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CHARLES F. MARVIN, Chief

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INTRODUCTION.

The MONTHLY WEATHER REVIEW contains (1) meteorological contributions, and bibliography including seismology; (2) an interpretative summary and charts of the weather of the month in the United States and on the adjacent oceans; and (3) climatological and seismological tables, dealing with the weather and earthquakes of the month.

The contributions are principally as follows: (a) Results of the observational or research work in meteorology carried on in the United States or other parts of the world, in the Weather Bureau, at universities, at research institutes, or by individuals; (b) abstracts or reviews of important meteorological papers and books, and (c) notes. In each issue of the REVIEW reviews, abstracts, and notes are grouped by subjects, roughly, in the following order: General work, observations and reductions, physical properties of the atmosphere, temperature, pressure, wind, moisture, weather; applications of meteorology, climatology, and seismology.

The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, **but the publication of contributions is not to be construed as official approval of the views expressed.**

The partly annotated bibliography of current publications is prepared in the Weather Bureau Library. *Persons or institutions receiving Weather Bureau publications free should send in exchange a copy of anything they may publish bearing upon meteorology, addressed "Library U. S. Weather Bureau, Washington, D. C.,"* in order that the monthly list of current works on meteorology and seismology may be as complete as possible. Similar contributions from others will be welcome. Bibliographies of selected subjects are published from time to time in the REVIEW OR SUPPLEMENTS.

The section of the weather of the month contains (1) an interpretative discussion of the weather of North America and adjacent oceans, and some notes on the weather in other parts of the world; (2) details of the weather of the month in the United States; and (3) brief discussions of weather warnings, rivers and floods, and weather and crops. There are illustrative charts. The climatological tables comprise summaries of the weather and excessive precipitation data for about 210 stations in the United States, and summaries of the weather observed at about 30 Canadian stations.

It is hoped that the meteorological data hitherto contributed by numerous independent services will continue as in the past. Our thanks are due especially to the directors and superintendents of the following:

The Meteorological Service of the Dominion of Canada.
Meteorological and Seismological Service of Mexico.
The Meteorological Service of Cuba.
The Meteorological Observatory of Belen College, Habana.
The Government Meteorological Office of Jamaica.
The Meteorological Service of the Azores.
The Meteorological Office, London.
The Danish Meteorological Institute.
The Physical Central Observatory, Petrograd.
The Philippine Weather Bureau.

The seismological tables contain, in a form internationally agreed on, the earthquakes recorded on seismographs in North and Central America. Dispatches on earthquakes felt in all parts of the world are published also.

Since it is important to have as the name of the month appearing on the cover of the REVIEW that of the period covered by the weather discussions and tables rather than that of the month of issue, the REVIEW for a given month does not appear until about the end of the second month following.

SUPPLEMENTS, containing kite observations, and others, containing monographs or specialized groups of papers, are published from time to time.

NOTES TO CONTRIBUTORS.

Authors are requested to accompany their papers submitted for publication with a brief opening synopsis. When an article deals with more than one subject—as, for example, a method of measurement—some experimental results and a theory, each subject should be summarized in a *separate paragraph*, with a title which clearly describes it.

When illustrations accompany an article submitted for publication in the MONTHLY WEATHER REVIEW, the places where they should appear in the text should be indicated, and legends or titles for them should be inserted just after the end of the article. As far as practicable the illustrations when accompanied by their legends should be self-explanatory—i. e., the data on them should leave no doubt of what they are intended to convey.

BACK NUMBERS OF THE REVIEW WANTED.

The Weather Bureau has not enough of the following numbers of the MONTHLY WEATHER REVIEW to meet even urgent requests for filling up files at institutions where the REVIEW is constantly being referred to. The return of any of these or of any 1919 or 1920 issues, especially November, 1919, will be greatly appreciated. The attached addressed franked slip may be used for this purpose, or one may be had on application to the Chief, U. S. Weather Bureau, Washington, D. C.

1914: January, February, March, April, September, October, December.
1915: May, June, July, August.
1916: January, August.
1917: June.
1918: February, September.
1919: Any issue, especially November.
1920: Any issue, especially January.
SUPPLEMENT, No. 3.

CORRIGENDA.

REVIEW, November, 1919:

Pages 782 and 784, figures 10 and 11, the legends "(Gram-calories per minute per square centimeter)" *should read* "(Gram-calories per square centimeter)".

Page 787, figure 15 (b), latitude "12° N." *should read* "42° N."

Page 830, bottom line, eighth column, "−1.2" *should read* "+1.2".

MONTHLY WEATHER REVIEW

CHARLES F. BROOKS, Editor.

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THE AURORA OF MARCH 22-25, 1920, AND ASSOCIATED DISPLAYS.[1]

By Charles F. Brooks and Herbert Lyman.

[Weather Bureau, Washington, D. C., Aug. 25, 1920.]

SYNOPSIS.

A disturbed area marked by a group of sunspots stretching more than a quarter of the way across the face of the sun, bombarded the earth with such an abundance of electrified atoms that it caused an intense magnetic storm and an extraordinarily active and brilliant aurora, lasting for 20 hours and followed by 3 days of lesser magnetic and auroral activity. The beginning of the aurora was observed at Tatoosh Island, Washington, and in Australia practically simultaneously; then it became visible at dusk successively around the world until the last of its brilliance was seen toward dawn in the northwestern United States.

The numerous reports show not only that the periods of greatest brilliance and maximum magnetic activity were simultaneous throughout the world, but also that the general aspect of the display as a whole was similar. The local differences depended largely on the positions of the observers relative to the great series of auroral curtains. Great activity, some brilliant colors, especially crimson, and great vibrations of the whole display were characteristic features.

Some 100 reports received from parts of eastern North America have made it possible to map the actual locations of the brilliant auroral curtains at particular times, and thus to picture what might be called the geography of the aurora.

Auroras and magnetic disturbances occurred in mid-February, mid-April and mid-May, during the preceding and following presentations of the same active region on the sun, as it rotated.

This aurora ranks among the greatest five world-wide displays of the past 5 (or, in fact, 11) years, embracing the recent unusual sunspot maximum. In many places this aurora was the most brilliant one seen in this century.

INTRODUCTION.

Of all the phenomena of the heavens, what can vie with the magnificence of the aurora? Those who saw the display of the night of March 22-23, 1920, in all its grandeur, whether in France, England, or the northern half of the United States, have found it impossible to give an adequate word picture of the beauty of the sky filled with a ribbed dome and waving colored curtains of flaming lights.

The various descriptions received from places throughout the length and breadth of the United States, from Canada, from steamers on the Atlantic Ocean, and from Great Britain, France, Switzerland, and Germany, show that this aurora consisted of a great number of luminous curtains, extending, roughly, east and west, joined by an uneven sheet of light and grouped together into two great belts, probably encircling the north and south magnetic poles, with its outer edge at a distance of 3,500 to 4,000 kilometers, and most brilliant in apparently the outer 500 or 1,000 kilometers.[2]

THE LONG SUNSPOT GROUP.

What made this display, and when did it start?

"On March 19 a new large group [of sunspots] was seen near the east limb [of the sun], showing remarkably complicated structure. The whole group extended over about one-fifth of the solar diameter, and observations on March 22, 23, 25 indicated rapid variations. There were three main spot centers, occupying the preceding and following ends and the center of the group, respectively, while the whole of the intermediate area was occupied by a great number of small umbrae. Spectro-heliograms on the above days, taken in calcium light, show the whole group as a connected mass, but the accompanying flocculae were not specially prominent. It is interesting to note that this spot group was at very low solar latitude, almost equatorial, and that it passed central meridian about March 22."—*The Observatory*, April, 1920, p. 166.

"It was the biggest group of sun spots observed since August, 1917, and its disk area, in units one five-thousandths of the visible disk, was 34 on March 22."—*A. L. Cortie.*[3]

"Not since the founding of the [Juvisy] Observatory [France] in 1883 had such a long group of sunspots been seen as were visible even to the naked eye after March 15. It was at least 500,000 km. long, measuring 22 mm. on the photograph in which the sun's diameter is 80, and the diameter of the earth on the same scale is less than 1 mm."—*G. Renaudot.*[4]

THE MAGNETIC STORM.

The arrival of the first cloud of electrified particles from this active area on the sun was registered at magnetic observatories throughout the world, in high as well as in low latitudes, simultaneously March 22 at 9h. 9m. G. M. T. (Among 10 observatories 9h. 6m. is the earliest and 9h. 12m. the latest time of beginning noted.)

"The [magnetic] storm began abruptly * * *, four hours of moderate activity being followed by about 6 hours of much greater activity. After a lull in the storm for three or four hours, the most severe portion began an hour or two before midnight [G. M. T.] and continued up to about 7h. on the 23d. The principal portion of the storm ended about [two or] three hours later, but there was considerable activity, particularly at Sitka, up to the end of the 25th."—*D. L. Hazard.*[5]

We should expect from this that there would be relatively little auroral activity from 9h. to 13h., a considerable display from 13h. to 19h., relative quiescence from 19h. to 22h. or 23h., great auroral brilliance from 22h. or 23h. till 7h. on the 23d, and considerable aurora from 7h. to 9h. or 10h., followed by a moderate aurora till the end of the 25th.

THE AURORA APPEARS IN BOTH HEMISPHERES.

The aurora was first observed almost simultaneously at 12h. 55m. G. M. T. at Tatoosh Island, Wash., and at 13h. at Cape Leeuwin (lat. 34° S.), West Australia:

1. *Tatoosh Island, Wash.*—A vivid aurora was observed from 4:55 a.m. to 5:17 a. m., extending from WNW. to ENE., and within a few degrees of the zenith. It consisted of large streamers at uniform distances from one another with smaller and less vivid streamers between them. About one-third of the way down from their upper extremities their color was a reddish hue; this color also showed on the sky between the streamers and extended down several degrees, constantly changing like the reflection from the sky of a distant fire.—*C. D. Asher* (U. S. Weather Bureau).

[1] Presented in part before the American Meteorological Society, Washington, D. C., Apr. 22, 1920.

[2] See Elias Loomis, "A treatise on meteorology," etc., New York, 1885, p. 187, for a map of auroral activity in the northern hemisphere. The whole section, pp. 173-201, includes an interesting exposition of facts concerning the aurora polaris.

[3] Nature (London), Apr. 1, 1920, p. 137.

[4] L'Astronomie, Apr., 1920, pp. 154-155, with photo of sun Mar. 22. For a photo of the sun Mar. 23, see *Popular Astronomy*, May, 1920, plate 14, and for a discussion of its appearance on the 23d and speculation as to its relation to the aurora, see *Science*, May 14, 1920, p. 486.

[5] Terr. Magnet. and Atmos. Elec., June, 1920, vol. 25, no. 2, pp. 57-59. See also pp. 60 and 61, and *Nature* (London), Apr. 1 and 8, 1920, pp. 136-138 and 170, for detailed accounts of foreign observations.

"According to the 'West Australian,' Perth, March 24, 1920, fine auroral displays were observed by the lighthouse keeper at Cape Leeuwin from 9 p. m. to 3 a. m. [13^h–19^h G. M. T.] on the night of March 22 to March 23, at other stations along the south coast as far as Adelaide, at Kalgoorlie, and faintly at Perth about 3 a. m., March 23."

"An aurora was observed between 2^h and $2^h\ 30^m$ [120th E. mer. time] on March 23 [at Watheroo Magnetic Observatory, West Australia]; it appeared as a pale, but distinct, pink glow above the clouds [the dark segment?] on the southern horizon, losing color and fading away gradually."[6]

An hour before the aurora was last seen in Australia it became visible in Europe.[7] When it was so bright in Australia as to be visible at Perth (19h. G. M. T.) the whole northern sky as seen from near Hamburg, Germany, was covered with such a bright sheet of auroral light that second magnitude stars could hardly be seen. Two bands across the sky looked as bright "as if lighted by the full moon when rising." The disappearance of the display after this in Australia was marked in Germany by a rapid retreat of the lights toward the north and a marked decrease in brilliance.

A well-defined arch with a dark segment in the north first became manifest at 19h. 17m. (G. M. T.), and immediately thereafter the display began to increase in brightness and to show beautiful patches of crimson light. At 19h. 30m. the light was bright enough to distinguish pencil writing but not to read. The dark segment reached to a height of about 14°, indicating that the arch must have been overhead across Denmark and south Sweden. At 19h. 53m. the display rapidly collapsed, and the dark segment approached the horizon; at 20h. 38m. the light extended all the way to the northern horizon. Thick fog then blotted the display from sight.[8]

The aurora, however, was still visible in East Prussia till 1h. (G. M. T.), March 23.

In a short note, Dr. J. Maurer, director of the Swiss meteorological service, says that this aurora was seen even from southern Switzerland, and that this was the first impressive display since that of September 9, 1898. In fact, there has been an unusual scarcity of auroral displays in Switzerland since 1875. Prior to that there was a period of relatively frequent auroras from 1830 to about 1870, when the last great aurora of this long series occurred.[9]

THE SECOND BRILLIANT PHASE BEGINS.

With the beginning of the magnetically active period, long vertical rays were seen to shoot up from the previously quiescent auroral glow in the north, as seen from Juvisy, France. But the activity died down at 23h. 40m., and at 23h. 45m. there was only a feeble luminous arc near the horizon. Rejuvenation took place during the next ten minutes, followed again by a weakening. This section of the display was finished with a brilliant intensification of the light in an arch covering all the NW. and N. sky at 23h. 58m. At 1h. the 23d (cf. 8 p. m. in the eastern United States, see below):

"The spectacle became prodigiously beautiful; the aurora developed in all its splendor; the northern sky was covered with a brilliant phosphorescence, streaked with gigantic rays in the north up to the Great Bear, nearly to the zenith, in the west to the brilliant Jupiter, and also to the east, to the northeast, in all directions of the sky on an angular extent of more than 180 degrees. And *all this fiery luminosity was in vibration*, animated by strange pulsations. [At 1h. 30m. the lights had died down, as in the U. S.]"—*G. Renaudot.*[10]

The vibrations of light, so noticeable in North America during this display, began simultaneously in Europe and the United States, being noted at 1h. 22m. G. M. T. at Washington, D. C. In other respects, likewise, the aurora at Washington was much the same.

The display was also seen in Great Britain. At Eskdalemuir (lat. 55¼°), Scotland, there was "an auroral display, including the 'curtain' form at a considerable altitude, and extending at 0h. 50m. on March 23, to within 30° of the southern horizon."—*A. C. Mitchell.*[11] [Compare Alexandria Bay, N. Y., no. **24**, p. 385, below.]

"I had a fine view of this superb display at Workington (lat. 54½°) [England] between midnight and 1 o'clock a. m., in a clear and bright starlit sky. The whole sky was filled with the light except a small area in the southeast. I could detect no color except creamy white, the general intensity being, to my mind, at times equal to full moonlight. Curtains of light surrounded a point just east of the zenith, which seemed to mark the 'hub' of the display. The bright star (α) in Canes Venatici almost exactly marked this point, and filmy sheets of light seemed to dash upward from the southwest and northeast horizons and merge together at this star. The only display I have ever seen to equal this was on February 14, 1907, at Motherwell, in the previous sun-spot maximum period. It was the fact that I could see the great sun-spot train on March 22 without telescopic aid that made me expect and look out for the aurora that night.—*W. B. Housman.*[12]

"On going out of doors at about 3.15 a. m. [at Whalley (lat. 53¾°), England] * * * the aurora was exceedingly fine * * * [and] consisted of about eight broad beams of light, most of which, except the extreme west and north ones, extended to within 5°–10° of the zenith. The lights extended over about 90°–100° from approximately north-northeast to west by north.

"The beams became pale and brilliant again several times, besides constant slighter variations in intensity. On two or three occasions, within about 20 minutes, most of the beams, more than three-quarters, disappeared, leaving one or two longish ones. The color was mostly white, but sometimes reddish in parts, especially nearly due north.

"A curious feature was an oblique band of light, which came and went across near the summits of the vertical beams. I do not think this was a belt of illuminated cirrus, as its brightness seemed to vary independently of the vertical beams, but it is possible it may have been. The lights had diminished considerably by about 3.45 a. m., but had brightened again, though slightly, when I looked out a few minutes later. I do not know what time the display ended."—*Lt. Col. Penny.*[13]

Two reports were received from vessels on the Atlantic Ocean:

2. Br. S. S. *Hotham Newton*, Captain Fieldgate. Observer H. Bird.
P. m. of March 22 and a. m. of March 23. Brilliant display of aurora borealis. Moderate N. W. wind and sea. Latitude 42° 33′ N., longitude 51° 00′ W. (No exact time given.)

3. Am. S. S. *West Togus*, Captain Dowling. Observer B. C. Watson, 2d officer.
March 22, 8 p. m. to March 23, 2 a. m. Observed very brilliant northern lights covering entire sky, and at times of deep red color.
Approximate position: 42° 20′ N., 62° 30′ W.

THE DISPLAY IN NORTH AMERICA.

The best opportunity for widespread observation of this great aurora came to the people in the eastern United States and Canada. The most severe portion of the magnetic storm occurred, conveniently, in the period between 5 or 6 p. m. and 2 a. m., Eastern Standard Time, and the skies were cloudless over a large area. Judging from the European reports, there was no very brilliant phase in this period till about 7:55–8:15, so we really did not miss much of the display during the last two hours of daylight.

[6] *Terr. Magnet.*, etc., June, 1920, pp. 61–62.

[7] At Pillkallen, in East Prussia: *Met. Zeitschr.*, May, 1920, 37:130–132, mentions six places in Germany where the aurira was seen, and contains a detailed account of the display from 18h. 59m. to 20h. 47m. (G. T. M.), as seen from near Hamburg, and briefer accounts from Potsdam and from Switzerland.

[8] Abstracted from account by K. Graff, ibid.

[9] Ibid., p. 132.

[10] Translated from L'Astronomie, Apr., 1920, p. 154. The whole account covers pp. 153–156, and there are other short descriptions, pp. 156–158.

[11] *Nature* (London), Apr. 8, 1920, p. 170.

[12] Ibid., Apr. 15, 1920, p. 200.

[13] Ibid., Apr. 1, 1920, pp. 137–138.

GEOGRAPHICAL VARIATIONS IN ASPECT.

As usual, the aspect of the aurora varied from place to place and from time to time. This was owing to a number of factors: (1) The curtains do not look the same when viewed from different angles; (2) they are not uniformly bright nor uniformly colored; (3) the aurora is in motion—the whole display rotates westward as the earth turns under the more or less stationary magnetic field, the curtains move southward, their folds and other streamers unfurl eastward and westward and their lights flash upward individually and wave upward in unison.

In spite of these movements, the occurrence of periods of marked intensification of the lights, wherever they happen to be, is shown in the descriptions; and thus permits of an attempt to map the positions of particular auroral curtains at certain times. The possibility of such mapping is rendered simple by the fact that the bases are at practically the same altitude—about 100 kilometers. But its actual accomplishment is difficult without reports of angular heights of the under apexes of the brighter arches at particular times. Fortunately, there were enough of such angular heights estimated, and enough reports from places directly under such curtains to determine their positions at times when the display of March 22–23 was unusually bright.

Before discussing further the geography of this aurora, it would be well to introduce some of the accounts themselves to show how the features seen in one part of the sky from one place are visible in another part of the sky from another locality.

AN AURORAL CROSS-SECTION VIEWED FROM SOUTH TO NORTH.

The brilliant curtains which at about 10 and 11:10 p. m. (75th mer. time) were directly overhead, respectively, at about latitudes 37° and 38° across central Virginia, were described as follows at selected places south and north of them:

4. *Bradentown, Fla., lat. 27½°.*—* * * As we drove in our front gate * * * we noticed the bright glow over a large area in the northern sky. At first we thought it must be the reflection from a fire but * * * the glow was too pink. * * * A dark wave passing rapidly across the glowing surface, the light coming out again immediately following the dark wave, caused me to recognize it as an aurora. * * * The dark waves in this instance passed from right to left (east to west) three or four times while we were watching it. * * * In the glowing area I noticed several faint streaks shooting in or across it from south to north. It was about 10:15 p. m. [90th mer. time] when we first noticed it and after putting up the horse and going to the house I could still see a faint glow.—*F. H. Braymer.*

5. *Leesburg, Ga., lat. 31¾°.*—A faint aurora was observed between 9:15 and 10:15 p. m., having a reddish base with a few streamers projecting from it. Due to the presence of alto-cumulus and strato-cumulus clouds at this time very little of the aurora could be seen. First seen about 9:15 p. m. and entirely disappeared at 10:15 p. m.

6. *Augusta, Ga., lat. 33½°.*—The aurora first appeared in a direction NNE. as a luminous white streak along the horizon. It rapidly grew brighter in the north and threw out streamers which had the appearance of the beams from a giant searchlight. These beams moved across the sky in a northerly direction and reached an altitude of something over 45°. The aurora gradually turned from white to yellow, then to pink, and finally to a deep red, which slowly faded out. The display began at 9:45 p. m. and ended at 10:10 p. m.

The Western Union and Postal Telegraph companies reported all lines affected practically all day, the trouble being worse during time of the display and on lines running north and west.—*Louis A. Sledge.*

7. *Columbia, S. C., lat. 34°.*—An auroral display was observed in the north from dark to about midnight of the 22d. The arch was not particularly noticeable until about 9 p. m., except a rim of hazy, whitish light in a circle above a dark bank, rising about 10° above the northern horizon. Toward 9 p. m. the white light assumed a reddish hue, and occasionally reddish streamers * * * [5 to 10 times as long as wide] would shoot above the dark bank and move toward the east, finally dissipating; this continued until about 9:45 p. m., when the display was at a maximum, and the general light effects were distinctly reddish; after 10 p. m. the light gradually changed to whitish, with occasional flickerings. The aurora was last observed about midnight, when the white circle was very indistinct. * * *

8. *Wilmington, N. C., lat. 34¼°.*—Auroral display observed from 7:15 p. m. until dawn of the 23d. It had the appearance of a faint, misty light extending about 60°, centered along the northern horizon, its average altitude being about 25° with occasional thin, faint shafts of light reaching an altitude of 50° to 60°. Its color was mostly a yellow tint but for a short time it had a faint rosy hue and toward morning took on a greenish tint.

9. *Greenville, S. C., lat. 34¾°.*—At about 10:15 p. m. a very bright and spectacular ribbon of light, or streamer, on the extreme right of the display, varying in color from a violet to greenish outstanding, extended nearly to the zenith, the other lights generally of a golden glow gradually receding to the horizon. The entire distance along the horizon in the northern sky was about 60°. The brightest was over at 10:30 p. m., after which there was more or less a steady glow of a golden appearance near the horizon into the later hours of the night.—*Prof. M. E. Brockman.*

10. *Charlotte, N. C., lat. 35¼°.*—* * * As soon as the twilight disappeared, the aurora was seen in full brilliancy, extending around the northern horizon for 45°, with its center directly under the pole star and extending up to the Little and Big Dippers, which were nearly overhead at midnight.

Streamers of white and pink-blue light could be easily traced, wavering like moving pictures on the sky. The aurora was the finest about 45° above the horizon. Its upper limit was a great arc, which had its highest point near the pole star, curving gradually to the horizon 22½° on each side of the north point. [The display was visible till near dawn.]

11. *Asheville, N. C., lat 35½°.*—A brilliant aurora was * * * first seen about 10 p. m. and continued until nearly morning [of the 23d]. * * * Streamers extended upward nearly to the zenith and * * * the colors were brilliant.

12. *Wytheville, Va., lat. 37°.*—* * * When first seen 8 p. m. the entire heavens seemed alight, many people thinking a large fire was in progress. Colors were mostly golden, yellow, and red with varied combinations. * * * In the north, below the illumination, an apparent wall of dark cloud[?] was observed. From a little west of north wavering streamers shot across the sky well to the south, while in the north and to the northeast shimmering undulating waves of golden, yellow, red curtains would flash beyond the zenith.—*J. S. Widmeyer.*

13. *Norfolk, Va., lat. 36¾°.*—* * * At 8 p. m. a faint arc with an altitude of about 30° extending from northwest to northeast, and of a light green color, was observed. The background was unusually black. No vibrations or streamers were observed until 9:55 p. m., when suddenly there appeared streamers out of the whole arc which extended nearly to the zenith. The color of the streamers was light green, except in the northeast where the streamers were of a rose hue. At 10:05 p. m. the streamers disappeared and the background became brighter, but the arc was still visible at 10:45 p. m.

The appearance of a curtain overhead is described in parts of most of the longer accounts published below. As the curtain nears the zenith, the converging rays of its folds (really almost parallel, but converging in the distance) seem to shoot at a target making the auroral corona at the "magnetic zenith" a few degrees south of the true zenith. Almost simultaneously from the eastern and western horizons the light rises in great serpentine waves or spirals up which meet with a flood of light at the corona. To illustrate here are descriptions of curtains overhead as seen at Gloucester, Mass., and New Haven, Conn.:

14. *Gloucester, Mass.*—* * * The most striking effect was that of irregularly curved bands of light, sometimes 50° in length, passing near the zenith, which would be strongly luminous for a few seconds and then a faint illumination would persist for several minutes. This was not due to persistence of vision, and the whole faintly luminous area would slowly drift toward the east, while occasionally new areas would flash up, the curvatures of which would be nearly parallel to the first. This occurred several times and once four areas were noticed simultaneously with the same general curvatures. The faint luminosity did not flicker but gradually disappeared, unless, as occasionally happened, it would again be illuminated, sometimes with one edge more brilliantly lighted than the rest, giving an edged curtain effect. The drift of the faint luminosity was distinctly toward the east by comparing it with stars, and immediately after the discharge its intensity seemed about that of the galaxy. Estimating the drift

as about 5° in 5 minutes and assuming the disturbance at 60 miles up would indicate a velocity of the ionized air of about 350 miles per hour.—*H. G. Dorsey.*

15. *New Haven, Conn.*—* * * At 10:00 p. m. * * * [a bright band] extended from near the eastern horizon in a long uniform curve to a point well to the southward of the zenith. When first observed its width was 5° or 6°, but gradually became narrower and as it did so took on a twisted appearance. * * *

Lat. 39°, Chevy Chase, D. C.—In the southern sky the lowest arch in broken form came within about 30° of the horizon at its under apex apex at 10:05 p. m.—*C. F. Brooks.* (For remainder of account see No. **18** below.

16. *Jericho, Vt., Lat. 44½°.*—The [display] was unusually brilliant, auroral rays extending low down clear around the horizon, centering overhead, center somewhat south of vertical, farther south than I ever saw it before. Pulsations of the rays were often unusually vigorous. The most remarkable feature to me was the great distance the aurora extended to the south, clear down almost to the horizon, especially in the southeast. There was an unusual brilliance of the rays and nebulous light far to the southeast in the evening (for some time), exact time not noted.—*W. A. Bentley.*

THE AURORA IN MOTION.

If these descriptions of the same curtain as seen from different latitudes were merged into a single account, and if that section describing the display from Florida to Virginia were repeated and woven into the account for Virginia to Vermont, we should have in its essential features a description of the display at a single place, such as Washington, D. C., as the curtains kept forming or appearing in the north, and traveled southward. In many of the descriptions the time-interval between the arrival of an arch at a height of 45° in the north till it reaches the magnetic zenith, where it forms a corona, is a matter of about a quarter of an hour or less. This indicates a southward speed of 400 to 1,000 kilometers per hour. For some specific details as to the movement of arches note the next to last paragraph in the account of the display at Wichita, Kans. (**17**), and the description of the display from 7:59 to 8:18 p. m. at Washington, D. C., (**18**).

As the curtains fade away in the south new ones come out of the north. At times during the display of March 22, five to ten curtains were distinguishable at the same time. (See the following descriptions).

17. *Wichita, Kans.*—A very beautiful display of the Aurora Borealis or Northern Lights, was observable in Wichita on Monday evening. While the display was for the most part rather faint, a great variety of auroral forms developed at one time or another; in particular a specimen of the so-called elliptical arc. The aurora was at first distinguished at 7:40 p. m., according to observations by Lincoln La Paz, at Fairmount College, as cloudlike masses of excessively faint light in the northern sky, and continued in a greater or less degree until after midnight. At 8:50 the auroral light became intensified in a long band stretching from northwest to the east point, and bright parallel rays of white light rising from this band made their appearance. By 9:04 the band had become a great elliptical arc, faintly greenish in hue, and the parallel rays were noticeably reddish near their summits. This was by far the most interesting phase of the spectacle, the arc expanding across the heavens like a wave on the surface of a pool until it passed the zenith and extended into the southern half of the sky.

After 9:10 the display began to diminish in brightness, but faintly red and green rays, with here and there a shaft of white light resembling a dim searchlight beam, endured 8 or 10 minutes longer. At its maximum the auroral light caused a noticeable illumination of the north walls of houses and occasioned a great deal of comment on the part of those who were fortunate enough to observe it. It is possible that the display seen in Wichita is only the southern fringe of such a nation-wide aurora as appeared in March, 1918.—*Wichita Eagle.*

The long band of intensified auroral light noted at 8:50 p. m. was, strictly speaking, a double arch [with ends and junction 11° above the horizon] * * *. The altitudes and bearings of the end points of the arches and of their point of intersection were determined using a transit from which the object glass and eyepiece had been removed; and the measures show that the junction of the arches was nearly on the magnetic meridian of this locality.

After 8:50 the aurora grew steadily brighter reaching a maximum at 9:04. At this time the double arch had been replaced by a single elliptical arc some 15° broad along the magnetic meridian and extending from N. 30° W. to N. 90° E. The lower sharply defined boundary of the arc remained sensibly stationary at an altitude of 10°, but the upper edge was soon observed to be swelling toward the zenith and about 9:06 it was seen to pass over the Dipper. The velocity of its expansion was such that it spread from Alpha to Beta Ursae Majoris in 30 seconds; however, the diffuseness of the wave front was such that the moments of its transit over these stars were uncertain to the extent of 2 or 3 seconds. At the moment that the front of the arc passed through the zenith it was seen projected on the sky as an appreciably straight line meeting the horizon in the points S. 80° E. and N. 80° W.; later as the arc-front descended into the southern sky it became concave to the south. At the time of maximum extent the auroral illumination spread along the magnetic meridian from an altitude of 12° in the northern sky to a point perhaps 20° south of the zenith. It is worth noting that the change in the direction of curvature mentioned above is what one would expect to observe during the passage through his zenith of the luminous plane whose south edge was approximately straight and all points of which were at about the same height above the earth's surface.

While the coloring of the aurora under discussion was far less intense than that of the one observed here in March, 1918, the variety of faint hues, the constantly changing forms, and above all the beauty of the expanding wave of auroral light lent to it an interest far greater than that of the earlier display.—*Lincoln La Paz (Physics Laboratory, Fairmont College).*

The following detailed descriptions from Chevy Chase, D. C., Hyattsville (10 miles east), and Cheltenham (20 miles southeast), Md., are presented here, as an example, to show the sequence of auroral events as visible from (essentially) one place:

18. *Chevy Chase, Washington, D. C.*—This great display was characterized by the following features (1) Unusual extent covering more than half of the sky most of the time, and over nine-tenths of it once; (2) softness of the light, which, in smooth whitish sheets, covered the sky with varying brightness, just as would cirro-nebula cloud of varying density; (3) relative shortness of the streamers, they were not hard in outline most of the time, as is usually the case, nor did they extend high above their respective arches; (4) general brilliance and occasional color, mostly crimson.

This display evidently started during the daytime, * * * for it covered much of the northern sky when first seen at dusk. At 7:34 p. m., when I first saw it, the northern sky up to the Pole Star was covered with a smooth, irregular whitish light from WNW. to ENE., giving more or less the appearance of smooth cirro-stratus clouds, with some holes in it. It had a general arch-like form. At 7:35 there was a temporary development of streamers in the north and east. At 7:43 the smooth, diffuse light had risen to the zenith.

BRIGHT PHASE, 7:43–8:24 P. M. (75TH MER. TIME).

7:43, streamers tipped at their lower limits by red light. Rapid lateral movement in the streamers.

7:48, the sharpest arch in the north was 10° above the horizon, leaving a dark segment immediately below it.

7:51, the arch in the northern sky took on the appearances of a hazily seen, bright curtain.

7:53, in the northwestern sky there were well-marked waves as if from the west in the diffuse light. The waves were apparently stationary and looked much like waves seen at times in stratiform clouds, though the sky was evidently cloudless at this time. These waves were most marked in the WNW. at about 20° above the horizon.

7:54, a number of streamers became crimson.

7:56, fair-sized patches of light in NE. and N. The auroral lights covered the northern half of the sky and some of the sky a little south of east.

7:57, general intensification of streamers.

7:59, for the first time a streamer was noted, in the dark segment, reaching down to the northern horizon. The top of the bright arch was 80° up in the north. Between the upper arch and the lower one the sky was covered with auroral cloud, more or less irregular in brightness.

8:00, the arch in the north was irregular on its underside, but the general elevation of the arched part was about 12° in the north. Edge of the upper arch reached Jupiter (about 17° south of the zenith).

8:01, the center of the arch passed Jupiter.

8:02, the arch reached Orion's belt.

8:03, the arch reached the middle of Orion's sword, fading out.

8:04, new intensification of streamers. Relatively smooth arch up to 12° in north. New wave of light reached Jupiter.

8:05, new wave of light reached Procyon (about 30° south of east-west line.

8:06, new wave of light reached Orion's belt.

8:07, new wave of light reached Saturn (about 20° south of east-west line) and top of Orion's sword. New curtain and dancers low in north.

8:08, crimson streamers in east. Five arches in northern sky.

8:09, light fading out at tip of Orion's sword. Faint belt reached Sirius (about 40° south of east-west line through zenith).

8:10, crimson light from eastern horizon up to zenith. Renewed brilliance in streamers Dancing in north and east.

8:12, another belt of light reached Sirius. Crimson in east fading.

8:13, irregular-topped, whitish belt of light nearly overhead.

8:14, crimson light in east and west and overhead.

8:15, new belt of light reached Saturn. Streamers brightening again, streamers short.

8:16, new belt of light to knees of Orion.

8:18, still another belt to Jupiter; that mentioned (8:16) last, gone.

8:19, new streamer display, very much like more or less irregularly-lighted narrow belts of cirrus east-west having sharp crosslines of falling snow.

8:21, half of corona.

8:22, first flickering.

8:24, display best so far.

RELATIVELY QUIESCENT PHASE, 8:28 TO 10 P. M.

8:28, much fainter flickers.

8:31, diffuse light overhead, half of sky particularly bright in NNW.-NNE., 15° to 60° up.

8:40, lights all over north half of sky, comparatively faint (relative to earlier brilliance).

8:50, lights over northern half of sky generally fainter except for a nearly perfect arch in the north.

8:51, temporary increase in brightness with some streamers.

9:20, arch in the north, 30° up, becoming double. Streamers through Jupiter and 10° farther toward the southeast. Display generally as at 8:51.

9:33, display knotty again.

(9:35–10:00, details not observed.)

THE CLIMAX, 10:01 TO 10:20 P. M.

10:01, suddenly getting brighter.

10:05, crimson, yellow, green, and blue lights unfurled in various parts of the sky. A brilliant piece in the NNE. showed all the colors of the spectrum for about a minute, the red being down. Round the magnetic zenith, radiating sheafs of brilliant red and green and blue appeared, completing the auroral corona. In the southern sky the lowest arch in broken form came within about 30° of the horizon at its under apex. Although a little of the horizon could not be seen, it appeared that the auroral lights extended to the horizon in the southeast and southwest. Practically the whole sky was pulsating with rising waves of light. A wave would take about a second to go from the Pole Star to the zenith.

10:05–10:12, an unusually bright crimson patch occupied the sky in the WNW. to a considerable height (about 60°).

10:15, the display had faded some. The flickering continued.

10:21, the streamers, the corona, and the flickering continued, the display still covering about three-fourths of the sky.

10:29, the display was again slightly on the wane.

10:53, the arch in the north was well defined and lower than before. The corona, the streamers, and the flashing of the lights were still present.

11:11, six arches of light in the north, not continuous. Three-fourths of sky affected by the aurora. Spots in the south visible only on flashes. Display still flashing. Red base to lowest arch in NNE.

11:12, two-thirds of corona again.

11:17, general crimson in N-NNE. Spectral colors on lowest arch, red at bottom.

11:20, bright corona, with white sheaf extending southeastward.

11:21, crimson in NNE. to NW. and W.

11:25, southern half of corona crimson for a minute. Much crimson in north high up, especially in NW. (a streamer).

11:27, flashing white light behind the crimson streamer. Display fainter.

11:58, height of underside of center of arch about 10° above northern horizon. Some streamers. Aurora over two-thirds of sky flashing moderately. Red on edge in northeast. Three-quarters of a corona.

11:59, brightening again in northeast.

12:06 a. m., arch in north broken up. Most of it bright whitish. Two-thirds of a corona.

12:17, brightening.

12:23, still bright. Two irregular arches in north, not as high as before.

12:30, two arches in west, bright. Part of corona still. Flashing spots in the south down to 45° or 60° above southern horizon.

[Mr. Fairfax Naulty, over the telephone, stated that he had watched the display for the rest of the night, and that about 2 a. m. there had been a maximum of brightness equaling, perhaps, that of 10 p. m.]

The time used in this description is Naval Observatory 75th meridian time. My watch was set at noon on the 22d and checked at noon on the 23d by the telegraphed ticks.—*Charles F. Brooks.*

19. *Chevy Chase, Washington, D. C.*—* * * As late as 3:30 a. m. the aurora was still making a fine display, though not nearly as spectacular as between 10 and 11.—*C. Waters.*

20. *Hyattsville, Md.*—The following [is a] copy of my notes taken March 22, about 10:30 p. m.: "First noticed dull glow, like before moonrise, from NE. to NW. with darker area lower down, about 7:30. Before 8 a good many changing streamers seen. About 7:50 to 8 was curtainlike with lower edge about 20° above northern horizon and light up to zenith.

"I was out again from 9:40 till after 10. There were at first faint zones of light from NW. to SE. and light playing back and forth on these like faint broad searchlight beams, but broken and irregular. About 9:50 there was a most brilliant waving curtainlike effect in the north, waving and changing like a rain of light all along the northern sky, with very dark below this irregular arch. About 10 this effect had spread over the whole sky. * * *."—*J. B. S. Norton.*

21. *Cheltenham, Md.*—The aurora was visible soon after sunset, but was first noticed by the writer at 8h 05m standard time. At 8h 10m a display of rays developed, proceeding from a bright band low in the northern horizon some 45° in extent. * * * The rays [at 8h 10m.] were visible from a point in the western horizon a few degrees (5°–10°) north of the new moon (azimuth from S=88°) to a few degrees in the eastern horizon east of Arcturus (azimuth=−76°.0), and apparently converged to a few degrees north of planet Jupiter (azimuth 26.5 and altitude 68°.5). There was a conspicuously rosy colored ray in the east. The rays lasted for about 5 minutes. The boundary of the illuminated area was parabolic in form. The ray display was followed by a general diffused glow.

At 9h 55m the diffused glow was bounded by a lighter arc extending from near the planet Mars in the east to some 15° south of Jupiter toward the west. At 10h 00m the rays were developed on a grand scale, and seemed to emanate from an altitude of 20° in the north and 30° in the south. The rays converged to a point half way between the star Regulus and the planet Saturn (alt.=62°, 5; az.=−11° .0). This ray display lasted 15 minutes, and then flickering movements became conspicuous. There was a rosy glow in the west. At 10h 40m nearly the entire sky was illuminated. At 10h 45m rays were visible in the north. Rays were again strikingly conspicuous from 11h 04m to 11h 15m; they converged from all directions to a point near Saturn (alt.=62°; az.=−12° .5) and were followed by flickering movements. Observations ceased at midnight.—*Geo. Hartnell,* Magnetic Observer U. S. Coast and Geodetic Survey.[14]

GEOGRAPHY OF THE AURORA.

Farther north, the display at dark had already reached into the sky south of the zenith. From all the accounts, especially from those which gave angular measurements or estimates of the heights of arches in the northern or southern sky at particular times, figure 1 has been constructed to show the positions of the brighter auroral curtains during the display. By 7:45 there were enough observers to make it possible to locate the position of the principal bright arch, across New England, central New York, and the Great Lakes. Another arch was observed some 200 kilometers north of Eastport, Me.(**22**).

At 8:15 when the whole display had reached one of its most brilliant phases, the southern arch had reached as far south as Richmond, Va., and there were pronounced general arches each with one or more curtains crossing the Atlantic coast district at about latitudes 39°, 42°, 46°, and 49°. For the relatively quiescent phase that followed no attempt has been made to locate the curtains. At the time of greatest brilliance of the aurora in the eastern United States, from about 10 to 10:05 the southernmost arch seems to have been at latitude 36, and the brightest curtains (Atlantic seaboard) at latitudes 37°, 39°, 41°, 42°, 44°, and 47°. That at 41° seems to have been the most brilliant. During the bright period at about 11:10 the principal curtains seem to have been at latitudes 38°, 39°, 41°, 42°, and 47°.

The positions of the curtains at 8:15 and 10:05 are shown on the map, figure 1, as are also the 74 numbered locations of the places from which descriptions of the aurora are being published in this article. The dots represent locations of other places from which information about the aurora was received.

[14] Excerpted from *Terr. Magnet.*, etc., June, 1920, pp. 59-60.

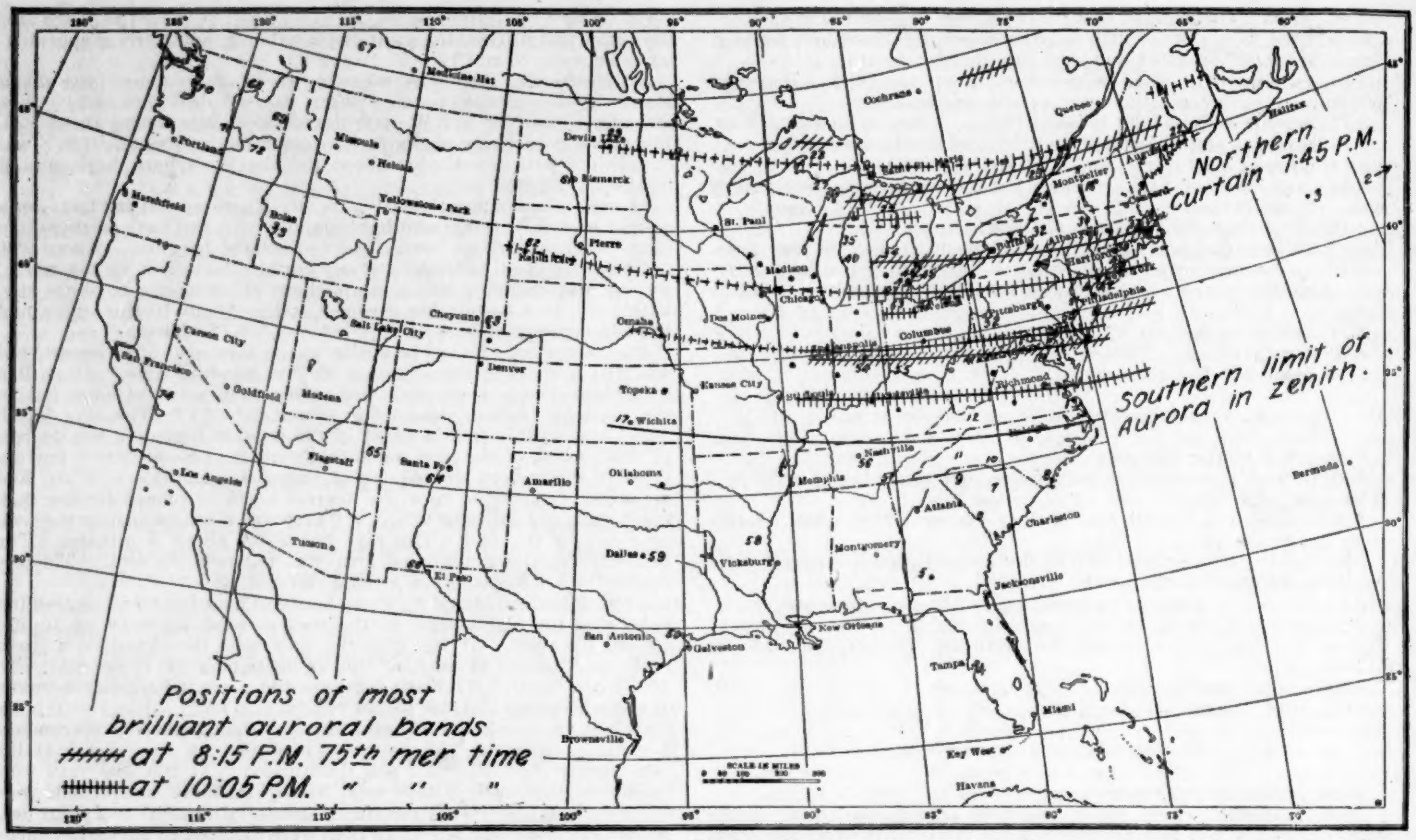

FIG. 1.—Auroral bands Mar. 22, 1920, and places at which the aurora was observed. Numbers refer to places for which descriptions are published in this article; dots indicate other places from which reports were received. (At 10:05 p. m. a bright auroral band, extending from southern Michigan to the Atlantic coast, which it crossed at about latitude 42°, is not shown on this map. It was immediately south of that indicated for 8:15 p. m.).

There is a striking similarity among the accounts of the aurora as seen in the same positions relative to the auroral curtains; i. e. in about the same latitude, even though separated by a thousand kilometers. The similarity is not so striking, however, between places in the eastern United States as compared with those in the western, for the two or three hours difference in the time of first being able to observe the display makes it impossible to compare the early phases. The following accounts are arranged, therefore, by auroral belts, and separately for the eastern and western halves of the country. It has been found impossible to publish all the descriptions received, on account of the necessity for restricting expenditures. The governing principle in selection has been the aim to show in full detail the sequence of auroral events at many places.

Thus, where long accounts were received from neighboring places, the most complete is published, with perhaps supplementary excerpts from the others. The information contained in the omitted descriptions has been found very helpful in the preparation of the discussion and especially of the map. All the original data will be placed with the material relating to the aurora of March 7–8, 1918[15] in the library of the Weather Bureau, Washington, D. C.

22. *Eastport, Me., March 22.*—An unusually brilliant auroral display visible from 6:50 p. m. to 11:30 p. m. Wide arch of about 5° and colored sea-green, altitude about 25°, azimuth about 150° to 210°. When first seen streamers of greenish-white starting at horizon reached beyond the zenith. Later there was a continuous pulsating in every quarter of the sky, with intermittent flashes, and very brilliantly colored "dancers" flashed rapidly from the eastern and western skies, and numerous streamers were also seen flashing in the south. The coloring was very brilliant at all times and tints noted were white, yellow, green, rose, and blue.

[15] MONTHLY WEATHER REVIEW, June, 1919, 47: 402–412.

23. *Ottawa, Canada.*—It was first observed about dusk or just after 7 p. m. on the night of March 22–23, 1920, when there were great pillars of flame as they seemed extending right across the sky from the west to the east or southeast, but particularly strong in the west. Many other streamers were present in the sky but were much stronger in the south and west than in the north and east; also a rather flat arc was present in the south. These variable streamers and waving curtains overhead continued practically throughout the night, but certain differences were noted as time went on. The playing "flames" were especially grouped or bunched overhead about 8:15 p. m. when there was a wonderful display of colors, red and purple and pink besides the prevailing green. (I did not see this display apparently but did see a similar one later—was informed of this one. (There was somewhat less activity after this till about 10 p. m. when there was one or more arcs present in the north continually from which curtains would spring and wave toward the south and west, still very little in the east. The smaller patches of glow which earlier in the evening had continually reminded one of comets with great bushy tails now became great masses and quivering beams of white or greenish-colored flame as they periodically brightened overhead and in spite of the street lights appeared to illuminate the surroundings with a peculiar glow. Every two or three minutes a beam would brighten up to great intensity, wave for a quarter of a minute or so and then rapidly die away again and be lost in the general auroral glow of the sky. At 10:20 p. m. I saw perhaps the most wonderful display of the whole gorgeous spectacle when directly in the zenith there appeared curtains, as if were skirts, waving and all bunched together as if suspended from an immense height and hung directly overhead. At first only a greenish shade they became tipped at their lower edges—really the brightest parts—with a beautiful purple, and because of so many waving together the purple was often all mixed up with the greenish part, but there seemed no doubt that really only the lower and brighter sections of each curtain was purple. This lasted less than a minute and after it the periodic auroral streamers did not seem to attain such intense brightness as they did before.

The aurora continued during the night but the above is a general idea of the phenomena. There appeared to be a considerable amount of cirrus or light haze all night and probably this along with the great intensity of the aurora made it often difficult to pick even bright stars like Regulus amid the strong streamers. The new moon was very beautiful early in the evening and in its arms could be easily seen the old moon. The aurora as usual seldom extended anywhere to near the horizon and beneath its border the sky was particularly dark though probably no clouds existed.

Mr. Dier informs me aurora always interferes with telegraphic conditions on east and west lines but not on north and south.—*J. P. Henderson, Dominion Astronomical Observatory.*

24. *Alexandria Bay, N. Y.*—After an extended period of apparent retirement, the aurora shone with a remarkable brilliancy on the evening of March 22d from about 7:30 o'clock until long past midnight which at the last observation appeared as an evenly distributed green glow almost over the entire sky.

The leading feature of this display and that which caused considerable comment was that the northern sky was dark except for a few stars shining hazily, but to the south and east and west from about 40° above the horizon to the zenith beautiful streamers of greenish hue flashed upwards where they formed a crown overhead. Later these streamers began coming up out of the northern sky and then words pale at the description. Still later the lights hung like a huge curtain in the northern skies constantly moving and shifting and with the many tints of the rainbow, but at all times green predominating. At one time the formation was that of a huge hook composed of yellow greenish light in rapid movement.

The plane of the lower limit of this aurora was well defined just as the plane of condensation appears in the cumulus cloud region on a warm summer day. The motion of the light was seemingly upwards as is observed usually in all displays.—*Douglas F. Manning.*

25. *Alpena, Mich.*—An auroral display of unusual brilliancy developed at 6:45 of the 22d and continued with varying splendor until just before daylight of the 23d. When it was first observed, it was a steady glow covering the entire southern sky, 270° through south to 90° azimuth. That part passing from east to west through zenith was particularly bright greenish white. In a few minutes it faded away near the southern horizon and the display became active north of the zenith and shortly the aurora covered the entire heavens. The waves of light had a greater tendency to progress rapidly in a lateral movement first one way and then another, instead of up and down. In the eastern and western skies, between 7 and 8 p. m., there was a pinkish cast to the display.—*F. Jermin.*

26. *Escanaba.*—A brilliant aurora was observed from 7:15 p. m. to 11 p. m. of the 22d. The first appearance was that of numerous streamers in the northern sky which converged at the zenith. By 8:30 p. m. the phenomenon assumed a more curtain-like appearance, investing the southern heavens as well as the northern. The greatest activity and brilliancy, however, prevailed in the northern quarters. The predominating color was greenish-yellow.

27. *Marquette, Mich., March 22.*—Aurora was first seen in north at 7:15 p. m.; brightest at 9:20 p. m.; last seen at 10:45 p. m.; azimuth from 1° to 360°; altitude, 90°. This aurora consisted of merry dancers and great fields of light that pulsated and waved from the east to the west. The color was ever-changing, and varied from a small amount of silver-white through gray to small areas of bright red to very large areas of dark red and almost black.

28. *Houghton.*—An usually fine aurora was observed on the evening of the 22d, from 7 p. m. to 10:30 p. m. The form was constantly changing, but during most of the time there appeared to be a nucleus, at times a vortex just south of the zenith, and from this streamers radiated in all directions. The colors ranged from white and yellow to purple and pink.

29. *Devils Lake, N. Dak., March 22.*—A bright aurora * * * was observed about 8:30 p. m. The arch was overhead.

30. *Hoosick Falls, N. Y.*—Except for intervals of a few minutes, I observed the display from 7:45 p. m. (eastern standard time) until 11:30. In the curtain form a very bright single ray ran directly from the zenith approximately 20° to the east and the same angular distance to the west. Extending about 8° in angular width toward the south from along the whole length of this ray there was a bright web of light, which resembled a curtain hanging in folds but lying horizontally instead of hanging vertically. Along the serrated southern edge of this web the light was much brighter at the place where the curtain had the appearance of doubling over upon itself. The whole formation was quite steady and would last five or six seconds without appreciable change; then, becoming unsteady, would quickly disappear and rapidly reappear in the same form, but slightly different as to details, chiefly length. The curtain formation was very bright when the sky was first observed at 7:45 p. m., and its brightness increased until a few minutes after 8 p. m., at which time it was so bright that the attention of everyone out of doors was at once attracted to the zenith. As observed here, this was the brightest, as well as the steadiest part of the whole display. During the next half hour or so the curtain faded rapidly until it was seen no more.

While the curtain display was in progress unsteady rays and shafts of light were appearing here and there, chiefly to the east and to the west, and they appeared to converge at a point located about 10° to the southeast of the zenith. As the curtain display faded, the converging rays became brighter. About the time the curtain finally disappeared these rays presented a curiously solid look to the eye, as if the hand was to be extended sufficiently high. Some of the rays appeared like shafts of light from a searchlight. This appearance was not noticed later. The rays were constantly in slow motion, sometimes a large portion of the sky being covered by them, and at other times only a few wisps of light being visible. Shortly before 11 p. m., the focal point seemed perhaps a trifle closer to the zenith than it did in the earlier part of the evening.

At intervals, while the ray display was in progress but apparently brighter when the rays were weaker, there were noticed diffused circular or oval spots of light toward the northeast at an average elevation of about 30°. These spots would persist for a half minute or so, and then would fade away without changing position.

By 10t30 p. m. the rays had much weakened, and it was supposed that the display was chiefly over. But at about 11 p. m. the rays brightened, increased in number, and became violently unsteady. Then, for 15 minutes or so, there followed the whirl form of display, which was perhaps the most beautiful part of the entire phenomenon. The sky overhead was filled with waves of light moving with great speed, crossing and intercrossing one another in all directions. The light waves appeared as if they were being driven by conflicting and interacting currents; and the sight at once suggested to the mind a view of the movements of snowflakes as seen above a city street during a driving snowstorm.

As if exhausted by this outburst, the entire auroral display weakened, and by 11:30 p. m. had become comparatively faint.

In color, the display overhead was whitish yellow, with a greenish tint; to the northward the greenish color was stronger; while toward the south there were slight touches of a pinkish hue. These differences persisted throughout the evening, although the whole display became slightly more pinkish as time went on. In addition, there were observed, now and then, a few very fleeting rays which appeared to have a reddish tinge.—*R. H. McEachron.*

31. *Albany, N. Y.*—* * * From my north windows I get a good view of the sky from about 20 or 25° east of north to the east, and I could look up to the zenith fairly well. At 12:15 a. m. Tuesday, March 23, on looking out of my northern windows I saw broad bands of silvery light welling up (I can choose no better word) approximately from NNE. to NE., which I at once recognized as auroral. The sky was cloudless; there was no moon, and the stars shone brightly. The light was silvery, devoid of any color, and there were no sharply defined rays nor any transient flashes. The appearance was that of great waving streamers, or broad ribbons somewhat resembling a searchlight, but without sharply defined edges, extending well to the zenith and what impressed me most, and seemed to me the most remarkable and unusual, was the appearance of the light in seeming to well upward as if ejected or projected and not as merely raying upward, and also and particularly the waving of the broad streamers, or banners. I had never seen anything of this nature before and it filled me with awe. * * * From my south windows a somewhat similar appearance presented. By 12:45 it had largely disappeared, and on looking out once or twice afterwards I saw no further display.—*W. G. Tucker.*

32. *Syracuse, N. Y.*—* * * Toward 9 p. m. I noticed folds or curtains in the east and toward the horizon beautifully colored tints. At 9:30 I observed that Sirius was well inside of the display, and the show was going on with unabated vigor. Again at 3:30 a. m. it was still going, and workmen observed it at 4:30. I didn't see it so well the next night, but it was felt by instruments. An interesting feature on the 22d was the playing of a most powerful Army searchlight on the sky during the auroral display. There was no possibility of mistaking one for the other, as they were seen side by side.—*E. D. Roe, jr.*

33. *York, N. Y.*—Display first noticed about 8 p. m. Luminous clouds seemed to form near the zenith and streamers to lengthen downward (although motion of light in them was upward) in all directions, first to north and west, then to east and south. The coloring was varied and distinct—red, pink, violet, and green, as well as an abundance of bluish white streamers. After covering nearly the whole sky for some time, with the exception of that portion less than about 10° from the horizon, the aurora subsided and before 9 p. m. only a diffuse glow in the north remained. About 10 p. m. renewed activity was noted. Swirling, cloud-like tongues of white fire rushed toward the zenith from the north and then from all points of the compass. Many times the corona appeared, faded, and reappeared. No coloring was evident at this time save a greenish tinge to certain patches in the north. The position of the corona, as sighted at the time (10:30 p. m.) and afterwards measured, was about 13° south-southwest of the zenith. At 10:15 p. m. there were two arches in the north—the apex of one being about 15° above the horizon and that of the other about 20°. These lighted up and faded several times, the illumination seeming to proceed from west to east in opposite direction to my previous observations on these northern arches. At times the corona showed a dark center and again it appeared as dense white cloud. About 11:30 the light became more diffuse, and at 11:45 only an unusual brightness in the north remained.—*Milroy N. Stewart*, cooperative observer.

34. *Saginaw.*—The aurora was observed at 6:35 p. m., continuing all night of the 23d into the early hours of the 23d. It died away about 4 a. m. of the 23d. It was first noticed as a colored arc, red to faint green from due northwest to east-northeast up to 5° north of Polaris, and streamers going up to 2° south of the zenith, meeting like the ribs of an umbrella. The whole cloud form followed at 8

p. m., covering three-quarters of the sky, only the southwest and west below Orion being free. There were comet-like heads appearing and disappearing, the waving curtains, the ascending smoke effect, and the rose-tinted clouds. At 10 p. m. there was a brilliant red to green arc about 10° above the horizon at the top, from due northwest to due northeast. At 10:15 p. m. there was a brilliant mantle meeting in a nebula-like head 2° south of the zenith. This corkscrew-like cloud flashed, appeared and disappeared. It would drift from the northwest, fade and reappear in the same position. At 11 p. m. a uniform white cloud with streamers and white mantles covered two-thirds of the sky. At times during the evening there were irregular clouds with rose-colored fringes at the bottom. The streamers and mantle took the form of an immense number of parallel white threads with strange dark lines at intervals within. The smoke effect seemed to be from lights running rapidly through cloud forms, giving the effect of smoke rising at enormous speed. The light of the display was often as powerful as a three-quarters moon.

35. *Ludington, Mich.*—Remarkable and brilliant aurora * * * beginning at about 6:45 p. m. and continuing to about 4:30 a. m. Most of the time the display consisted of bands and sheets of streamers, mainly whitish, mostly over the northern half of the sky, but in some degree also in the south, which extended upward and converged in a crown near the zenith. The crown was very pronounced at 7 p. m. At 7:12 there was an irregular arch with patches of various colors in the north. At 7:25 a diffused yellowish light covered most of the sky, increasing toward an arch of the same color in the south, beneath which the sky was dark blue. At 8:40 p. m. several whitish bands spanned the sky, through the termini turning toward the north. From 8:55 to 9:10 the crown was again pronounced and there were many streamers. At 10:20 p. m. and thereafter the display was less pronounced. At times during the evening long brightly colored streaks, one or two at a time, several vertical and several arched, would appear and drift across the sky. Not much flashing occurred before midnight, nor did the streamers in general move much to the eastward or westward. From about 2 a. m. to 3:30 a. m. there was remarkable flashing. The zenith crown was again distinct, and from all quarters of the sky, but mostly from the northern half, whitish sheets and streaks shot upward toward the crown. The spectacle was very impressive, the whole vault appearing to combine in the display. * * *—*C. H. Eshelman.*

36. *Westwood, Mass.*—* * * [at 7:45 p. m. the aurora] consisted of repeated folds of the "hanging curtain" type. The lower brilliant margin of the curtains reached an altitude about that of Polaris at 7:45 to 7:55, and the stronger folds or "pillars" extended to beyond the zenith. In addition to some wandering of the pillars to and fro, there was an expansion of the principal central fold of the curtain, so that pillars on the eastern edge were, on the whole, moving east and those on the western edge west. One or two more distant folds in the northeast were at this time exceedingly brilliant and the whole was remarkably clear-cut, in contrast with the blurring of the details which shortly succeeded.

The entire arch rose rapidly to the zenith and at about 7:55 and 8:05 its advance pillars, being seen end-on, gave repeatedly the most brilliant coronas I have ever witnessed. At about 7:55 the vanishing point of lines of light parallel with the dipping needle was observed to be about 2° W. of Jupiter and 2° to 3° N. of same. Ten minutes later the motion of the planet had carried it on until the coronal apex was 1° E. of Jupiter and 2° to 3° N. of it.

From 8:15 to 8:30, when the first and most brilliant set of curtains had passed south of the zenith, other not quite so bright series of curtains and broken arches had succeeded until the whole sky from 10° above the northern horizon to 20° above the southern was filled with patches of variously moving luminosity, but blurred as if seen through a lower phosphorescent film which dimmed the stars (previously standing out brightly on a cloudless sky). This film was not simply an ordinary cirro-stratus cloud, for it shone with a diffused glow of its own which illuminated the landscape with a peculiar shadowless light coming from every direction. There was continuous motion but it was ill-defined on account of the general obscuration by luminous haze. Others who were with me spoke of colors, but I saw only the prevailing greenish white.

At 9:30 the appearance had changed to that of serpentine bands extending in a generally transverse, i. e., east-to-west, direction. These came and went, flashing out briefly in the midst of the same indefinite general illumination which extended over a large part of the sky. Coronas were not evident, although the part of the sky where they had previously been, was still filled with light.

From 10 to 10:10 bright belts (N. to S.) were seen in the east, and, as it were, quivering flames southeast which, after 10 minutes, rose to the zenith.

At 10:20 a bright band (20° altitude) extended E. to W. in the north and bright cloud-like bands (N. to S.) in the east. General distribution of irregular patches and serpentine bands constantly quivering.

Shortly after 11 o'clock bright patches 40° to 50° broad were most evident in the east and west. The eastern one had upwardly-curving bands on its southern edge and flickered, but not through great stretches. The western mass continually cast up most vivaciously flickering "flames" which ascended upward and southward through 50° or 60° fading away to be instantly renewed in perpetual succession. This lasted a long time.

Four stages may be specially noted in this display:

1. The hanging curtains, pillars, and coronas, all sharply defined, the pillars moving to and fro, but not rapidly.
2. General luminous haze and indefinite mixed forms, continually changing, but ill-defined. Sky covered with luminosity from 10° above N. horizon to 20° above S.
3. Same, but more distinct bands extending in numerous serpentine lines in a general E. to W. direction.
4. Broad bright masses, curved streamers and flickering flames.—*Frank W. Very* (Westwood Astrophysical Observatory).

37. *Concord, Mass.*—The following is a copy of notes made on the display:

March 22. Fine display of aurora this evening. First noted at 7:05 p. m. when streamers and patches of pale greenish-yellow light appeared at intervals covering the entire northern and eastern heavens. At 8 o'clock a waving "curtain"-effect appeared in the west and northwest and this gradually gave way to fine, narrow yellowish streamers rising to the zenith with nearly the entire southern sky to within 30° of the southern horizon, pulsing with ever-changing "puffs" of yellow light. At this time no streamers or light of any description was visible in the northern sky. At 10 p. m. faint streamers came out of the NW. and rose to an altitude of 80°. Sky clear all the evening except for a few C. S. or A. S. clouds along the western horizon.

38. *South Hadley, Mass.*—[There were] * * * beautiful draperies or scrolls in the east and a lovely converging effect of streamers, like a shower bouquet. Point of convergence close to Jupiter between 7:30 and 8, when brightness was maximum. Tried to obtain spectrum with small (Schmidt & Hensch) direct-vision spectroscope. Saw four lines (or bands) not bright enough to get color. Twice while looking a sharp bright red line flashed out; heard the "Oh's" of students at the same time. There was a good deal of pink in the west and at points overhead. The draperies were white or greenish. Display lasted on and off all night.—*E. R. Laird.*

39. *Binghamton, N. Y., March 22–23.*—The most brilliant auroral display ever witnessed by the writer and the only one in 30 years' of observation of the night sky in this latitude in which the auroral curtain was seen south of the zenith occurred the night of March 22–23, 1920. The periods of rapid changes and more intense activity were for about 20 minutes each at 7:45 p. m., 9:45 p. m., and 12:30 a. m. During the remainder of the night there was a white, patchy auroral glow over the entire sky, with occasional streaks, that resembled thin cirro-stratus clouds illuminated by moonlight. The light cast on the terrain was equivalent to that given by the moon when nearing second quarter.

Vertical streamers from the northern horizon were not seen, and the center of activity, instead of being as usual on the northern horizon, seemed to be a little south of the zenith. Principal features of the display were: A brilliant northern curtain at 7:55; a corona and "flying eagle" at 8:08 p. m.; a dull northern arch at 9:50 p. m. which receded southward and became a brilliant curtain south of the zenith at 10:10 p. m.; a general white glow with patches of flickering light resembling heat lightning at 10:30 p. m., and a display similar to that of 8:08, which the writer did not see, at 12:30 a. m.

The northern curtain (seen at 7:55 p. m) was clear-cut, crenelated, and the sky toward the north was black.

The black silhouette of the "flying eagle" (seen at 8:08 p. m.) was sharply defined, the body about 1° long and the spread of each wing about 1½°. The position of the bird was as though flying toward the west with the wings outstretched toward the north, but it was stationary and a little to the south of the zenith. Innumerable dancing rays of light radiated out from it, with delicate shades of green and pink.

The southern curtain (seen at 10:10 p. m.) was also clear out and bright and was preceded by dull white, quiescent northern arch that bordered on the north the general white of the sky and then gradually rolled back to the south past the zenith and became transformed into the southern curtain. When the southern curtain was present the sky overhead and in the north was black, free from auroral light of any kind. The stars shone.

A noticeable feature of the northern curtain was its apparent nearness. It seemed to be at the usual height of cirrus clouds.

There were no clouds in the sky during the night.—*J. R. Weeks.*

40. *Grand Haven, Mich.*—Soon after 8 p. m. * * * a band of light with comb-like edges extended east and west through the zenith. It underwent rapid change of form. About this time streamers and coruscations began playing and shooting across the sky in all directions and from various points of origin. At about 8:30 p. m., southeast of Gemini a few degrees, there was a central area from which flame-like and fan-shaped flashes proceeded in all directions. * * * Faint separate flashes, resembling lightning, appeared in various parts of the sky interspersed among more distinct streamers. The entire display would at times almost cease throughout all portions of the heavens, and when it recommenced the luminosity would first be observed in

the north. Greenish-yellow was the most common color, but there also appeared reddish and bluish tints. The radiance much of the time was projected far to the south of the prime vertical, while in the southeast and south there persisted a whitish glow resembling the sky-reflections of a distant fire. The greatest brilliancy of the spectacle was from 8 p. m. to 9:30 p. m.—*H. Tullsen.*

41. *Ivoryton, Conn.*—Just before 8 o'clock * * * In the NE. and toward the N. there were shafts of light almost like searchlights that appeared to be coming out from behind clouds and shooting up into the sky, but I soon discovered that there were no clouds; the brightness made the sky close by look darker by contrast. All across the N. and NW. sky streamers of light shot up, meeting at the zenith, or rather a little to the SE. of it; in the NW. the light was more diffuse and pinkish, in the N. and NE. it changed constantly, now marching across the sky from N. to E., now appearing in horizontal streaks as the sun sometimes breaks through clouds just before it sets, now mounting in spirals of light, and oftenest of all looking like a curtain waving in the wind with light shining on its folds.

Sometimes all the light was gathered at the zenith like the folds of a tent, or as if one were looking at Mt. Fuji from above. The lights were greenish and yellowish white, with now and then fairly bright flashes of color, pink and green, gone almost before you could see them. * * * The finest of the display after 9 was at the zenith. At first the light was like thin, filmy white clouds, like the Milky Way, only brighter. One curious thing I noticed, it did not dim the stars at all; they shone equally bright through the clouds of light or in the dark spaces of the sky between. These clouds of light shifted and changed every instant, flickering like firelight, only faster; often the light would seem to start near the northern horizon and mount to the zenith by a series of flashes, like jerky moving pictures; sometimes it mounted by quite regular corkscrew spirals, but it all seemed to focus at the zenith. More light came from the NE. and N., but the central focusing point moved south, so I had to turn and face that way after a while.

All the light would gather overhead and the rays would spread over nearly the whole heavens; gradually the filmy clouds grew brighter and more solid; an irregular curve would flash off and on several times changing its shape very little and only gradually, it would be in the center of a dark part of the sky, the rays radiating from the outer circle.

Sometimes just overhead the light came and went like the little waves on the margin of the sand when tide is nearly out; all the time there was constant shift and play all over the sky. These lights were colorless; gradually they grew more stationary and still whiter; a river of light appeared to flow up from the NE. and cross to the W. one broader, brighter band and several dimmer ones parallel with it; off to the north was a small spot of light like the Magellenic clouds, and as the broad band gradually moved south this small, luminous spot moved, too, without changing its shape, keeping always the same distance from the broad band.

Then suddenly in the E. and NE. it grew very bright, so that the whole landscape was lighted up, and then the light was all concentrated overhead and there was a most wonderful display of light and movement with bands and spirals and spots of prismatic colors appearing and disappearing in flashes. It was like looking into an inverted cone made of rays of light. The colors were wonderful, pink predominating; sometimes a rosy glow was over large parts of it. This lasted perhaps two minutes, but not at the brightest that long; it gradually changed to white and shifting lights with one big, snaky spiral at the zenith and rays shooting up from the horizon. Later the flashes were white and like distant heat lightning in summer. There was a good deal of light in the south late in the evening; earlier there had been very little.

All the time the sky was clear and the stars very bright; a slender crescent moon was shining low in the west when we first went out, I kept thinking, clothed with light as with a garment. The light seemed to have body, as if you could grasp it as you could a curtain. After this we saw the Northern Lights several nights but only as streaks of light in the north, nothing to be compared to the display on the 22d.—*Ethel C. Comstock.*

42. *Plainfield, N. J.*—Phase "A" from 8:30, when I first noticed the aurora, to 8:45 was characterized by a moderately wide glow to the north with some streamers, though not brilliant, streamers with greater brilliancy, however, coming up from the east well toward the zenith. * * *

Phase "B," 8:45 to 9:45, showed comparatively little glow and scarcely any streamers from the north, but quite strong ones occurring a little north of west and with maximum strength almost due east, but extending both north and south of east. Streamers from the east seemed to preponderate slightly in brilliancy merging with those from the west in a fairly broad band of misty white light across the zenith.

Phase "C," 9:50 to 9:52, when I noticed increasing brilliancy and got to the roof, streamers were spreading from east and west rapidly toward the north and south to form as they did later a complete circle. The horizon, and up for about 30° or 40° was free from any light, comparatively black.

During the next three minutes, phase "D," 9:52 to 9:55 (please note that the times are merely guesswork as I did not take time to look at my watch while observing the aurora), shows increasing number of streamers and brilliant light, still white, equally distributed in all parts of the circle, extending from a distinct luminous circular boarder about 40° above the horizon, below which everything was black, to the zenith where at times there was a "hole" of complete blackness and at other times what looked like light, fleecy clouds swirling about. Of course, they were not clouds but had that effect, looking at the streamers endwise.

In phase "E," at just about 10 o'clock, I noticed a forked-shape light starting almost in the west from low down near the horizon, rapidly extending toward the zenith and growing tremendously in birlliancy until it attained the order of brilliancy of the moon on a clear night, and an equally brilliant light starting from the east and as rapidly as the one in the west, approaching the zenith, also growing more brilliant. This certainly started something up above. All of the streamers appeared to take on additional activities and iridescent coloring, especially all around the zenith, and extending practically down to the edges of the display, with a reddish color predominating toward the west. The east and west flares disappeared only to be followed by four or five other pairs of not quite so great brilliancy, starting simultaneously and reaching the zenith, disappearing together, each pair to be followed quickly by another. These flares, always in pairs, one east and the other west, so far as I observed, originated not more than 15° north of the east-and-west line, but the brilliancy of the dome or funnel above me appeared to be equal in all directions. Immediately at the zenith there was either a black hole of some 10° or else a swirl of fleecy "clouds."

This proceeding I suppose did not last more than 2 or 3 minutes, during all of which time there was no vibration apparent, except longitudinally of the streamers, i. e., radially from the circumference to the zenith, but at about 10:05, suddenly there were great concentric waves passing with great rapidity from the outer edge toward the zenith. I should say there must have been about 10 distinct waves visible at any particular instant and it probably did not take over a fifth of a second for any particular wave to pass from the bases of the streamers to the zenith. All of this is merely guesswork.

This manifestation of concentric waves appeared to be the beginning of the break-up. After they started there were no more flares of light such as had been occurring up to that time.

The iridescence disappeared gradually, except for a red glow which remained for some time in the west. The entire circular effect had practically disappeared by 10:15 and thereafter the aurora reverted to a condition similar to that from 8:45 to 9:45, and continued in that condition with more or less variation in brilliancy until 11 o'clock, at which time I retired. At 1 o'clock I was awake. It was then of considerable less brilliancy, the condition being somewhat like that at 8:45.—*Henry B. Newhall.*

43. *Cleveland, Ohio.*—An aurora of unusual brilliancy at this station was first observed at 8:30 p. m., with faint streamers and sheets of light in the east and west, and a pale light between. By 10 p. m., a spot about 15° south of the zenith began to radiate bands and sheets of light. The display reached its maximum brilliancy at 11:30 p. m. At this time the arch in the north became more prominent with rays of light shooting upward and with traces of the curtain effect below, but this was nothing compared with the display at the zenith, where ever-changing streams of light took on the greatest brilliancy. Sometimes these sheets and bars of light showed spectrum colors at the horizon. The display lasted to midnight and it was continuing at midnight.

44. *Detroit, Mich.*—An aurora which was first observed at 7 p. m. of the 22d continued until after midnight. When first observed the streamers of white were over the northeast and extending to the northwest; the streamers were not active at any time, but between 8 p. m. and 8:45 p. m. extended at times to the zenith. The white auroral nebulous cloud was observed during this period to the southeast and then south and clear around to the northwest; this cloud extended, however, from about 40° to zenith. There were no colors visible in the streamers except a very light crimson at times in the northwest. The dark auroral cloud was visible in the northeast. The display continued off and on until midnight. After midnight it was reported to be entirely confined to the south and was high at all times; the display lasted till about 1 a. m. on the 23d.

45. *Detroit, Mich.*—About 9:50 (eastern standard time) an arch approximately 9° wide appeared across the heavens from the northwest about 10° south of Jupiter, 12° south of Regulus, through Spica to the horizon a little east of where Mars had just risen. It seemed to be fairly uniform in width, but very irregular. This changed to a cone of light that stretched from the horizon on all sides to the apex, exactly in the radiant of the Leonids. At this phase it was so brilliant as to blot out all stars below the first magnitude. The colors were pale, except for a pronounced ruddy color south of Jupiter and Saturn. * * * The light was brightest in the south and southeast, but covered the whole sky. It occurred in spasmodic outbursts of brilliancy until daylight.—*W. B. Kennedy.*[16]

[16] Reprinted from Popular Astronomy, May, 1920, p. 308.

46. *Sandusky, Ohio, March 22.*—No clouds. Aurora first observed at 7:45 p. m. The northern sky had a luminous appearance with an arch extending from northwest to northeast from which bright streamers, of a greenish hue, extended toward the zenith. The greatest elevation of the arch was about 20° above the horizon. One streamer of a reddish tint was observed in the northwest. The greatest activity of this early display occurred between 8 p. m. and 8:15 p. m.; after a time the display became less bright, but the light of the aurora overspread the whole sky, except the extreme southwest portion, and gave to the sky the appearance of being overcast with a thin cirrus cloud-sheet. No particular changes were noted thereafter until about 9:45 p. m., at which time parallel bands of light extended across the sky from about 20° above the eastern horizon and from the Pole Star to the zenith. These bands rapidly converged, and at 9:55 p. m. two bright patches appeared at (about) altitude 50° and azimuth 125° [about over Ypsilanti; see **47**], and 305°, respectively. From these bright patches, which remained for about 10 minutes, greenish-white streamers radiated rapidly in all directions. From 10:05 to 10:15 p. m. the brightness of the aurora rapidly decreased, but at about 10:30 p. m. renewed activity was observed, the white cirrus-like sheet again overspreading nearly the whole sky with waves, not streamers, of white light extending from about 20° above the northern horizon to and beyond the zenith. This display was maintained for about 15 minutes, during which time the surface of the earth was lighted by the aurora nearly equal to that by the moon at quadrature. After 10:35 p. m. the display again decreased in brightness; the arch with streamers was again observed in the north, but the light was quite faint, and by 11:15 p. m. the display was practically over.

47. *Ypsilanti, Mich.*—These notes were written on the same evening that the observations were made:

"At 8 it was very brilliant in the north. The light at that time seemed to be in patches, changing to vivid vertical rays, that changed rapidly and shot up and down. This light would again change to a very bright narrow belt running from east to west but not perfecly regular. At times there were two such bright belts, not parallel, but more or less inclosing regular space. The entire aurora moved southward until before 10 it had passed through the zenith. At one time there was almost directly at the zenith a dark space, from which, as from a center, rays of light radiated. At another time a narrow band of bright light extended through the zenith from the eastern to the western horizon. Shortly after 10, almost the entire sky was filled with light. Flashes of light went in short, successive, pulsing waves from the eastern horizon to the zenith. At this time the sky was bright all around—north, south, east, and west. It was almost as bright as the light furnished by a half moon."

In addition to the foregoing notes, kindly permit me to add that the features of this aurora that distinguished it from others that I have observed, were the extraordinary brightness, the passing from the north through the zenith, until the auroral center seemed to be about 45° above the southern horizon, the pulsing waves that reached from the east toward the zenith, the unusual activity, and quickness with which the changes were made.—*Nathan A. Harvey.*

48. *Ann Arbor, Mich.*[17]—[At about 7:05 90th mer. time] * * * I noticed a few streaks in the western sky, but thought they were wisps of cloud. However, I soon became aware of their auroral nature. Then an auroral haze appeared, stretching along the equinoctial, from the horizon through Orion. Brighter streamers now began to shoot up from the northern, eastern, and western horizon and the flickering became noticeable. Until about 7:30, no color was seen, but the streamers then began to take on a light green tint which became more and more pronounced. The green was especially noticeable in the northeast where the aurora took the form of a beautiful curtain hanging down to within about 20° of the horizon at the north, arching upward to Mizar and downward to Arcturus.

Several times it appeared as if the display were coming to an end, but each time it began again, more vigorously than before. By 8:30 it covered practically the entire sky, the streamers flashing up from the entire circumference of the horizon and meeting, in general, at a point about 20° south of the zenith. (The dip of the needle at Ann Arbor is 73°; or 17° from the zenith). I will call this point the "radiant" for convenience. The haze in Orion had disappeared entirely by this time.

At about 9 o'clock, the streamers began to flash vigorously and they grew brighter momentarily. Suddenly there was a veritable explosion. Like flashes of lightinng, the east and west streamers shot up, glowing brilliant green * * *. A great double arch formed in the space of a minute or so. It stretched from west to east through the radiant. It was brilliant green with pale red borders and flashed like flame. In about five minutes it was gone, although fragments of it seemed to linger for some time. The entire sky within 30° or so of the radiant turned violet and the whole horizon glowed with a still brighter green than before.

Although the display was still quite brilliant it had now passed the climax. By 9.30 the region of the radiant had become dark; only an occasional flicker appeared there. The color faded also, and by 10:30 the greater part of the action was in the east and west, with only a slight tinge of green. At about 1 a. m. the activity had increased somewhat and the color had become more marked, but I did not observe it any longer.

During the display I noticed the following curious facts: Before midnight, in the northwest quarter of the sky, streamers forming in the north drifted slowly toward the west; in the northeast quarter, try as I would, I could not determine any definite drift. After midnight, in the northeast quarter, there was a drift from north to east, but I could detect no drift in either direction in the northwest quarter. Does this indicate solar influence? * * *.—*Dean B. McLaulghin.*

49. *Ann Arbor, Mich.*[18]—* * * Though active streamers and other features often centered in and toward the north and were delimited below by a marked black arch, at times perhaps the northern third or more of the sky was nearly devoid of visible aurora light while most of the rest of the heavens was illuminated. A well-defined *southern* black arch was seen at intervals, having a meridian altitude of perhaps 20° or 30°. When last observed (about 2 a. m.), there was no auroral light in the northern half of the sky. The southern black arch was well defined and above it was first a green arch and still higher a stronger one distinctly yellow in color.

About 10 p. m. an auroral curtain answering well to descriptions of such displays as witnessed in polar regions was observed in the southeast for about 10 minutes. This curtain was centered at an altitude of about 60° and extended some 30° right and left, with folds in an apparently vertical direction about 10° long. Shortly before this curtain appeared the light in the southeast was strong enough to cast a noticeable shadow.—*R. H. Curtiss.*

50. *Wilmington, Del.*—I first observed the aurora at about 7:20 p. m., when a few faint light green spots flickered around almost due north and 20° above the horizon. Within the next half hour these spots spread considerable toward the northeast and approached the zenith. Several times there were very well-defined examples of the spiral hanging curtain, so often illustrated in works of Arctic explorers. Very few spots of light pink occurred. The electrical impulses traveled upward from the horizon toward the zenith and at times markedly from the east toward the west (as if the earth were revolving through a field of such electricity). An hour or more later there was a very bright green spot to the west and about 30° downward from the zenith. This grew and spread with many fluctuations of brilliancy and in time the sky was almost entirely illuminated in light green, from the northern horizon past the zenith to 40°, approximately to the south of it, where the illumination terminated abruptly in a east-west line. The zenith was marked by a darker spot toward which long radiating lines extended from every direction, the electrical impulses traveling in pulsations along them from the horizon to the zenith. The light seemed to illuminate sheets and wisplike clouds of gas, the whole having the appearance of a luminous cloud. The appearance of convergence above must of course be due to perspective. When I retired at about midnight the display was still very bright.—*Alfred C. Hawkins.*

51. *Devon, Pa.*—* * * When first observed (midnight) the base was (eye measure) about 20° above horizon all round, south, north, east, west, rising to about 30° by 12:45 a. m. From ENE., round by north to NW. by W. (eye measure, no instruments) there was the characteristic arched base, but broken in places by irregularities. The rays above this base gave the impression of thicker mass and steadier glow—probably because the field covered was more extensive (thicker), but was not as bright as from ENE. to ESE., often WNW. to WSW., which I will call East and West, the rest North and South portions. The South portion was "thinnest" and had no well-defined base, and stars could be seen below and at times through it, but it was very exceptionally bright for any aurora in this latitude. It was rather more active than the North, but not as active as the West was most of the time. The East was far the most active, the West occasionally rivaling it. East was much denser than South, and generally [more so] than West, and occasionally as dense as North. Rays from all quarters met in roughly a circle about 5° in diameter with north edge about 10° south of zenith. * * * Sometimes rays from one side would reach it, sometimes from several or all quarters at once. It was the target for all rays and all long enough reached it.

The rays from the north moved less rapidly—about average for auroral rays I have seen. Those from south much more rapidly as a rule. The West were still more rapid, occasionally rivaling East (speeds of all probably the same, with general motion from the east—apparent differences due to relative distances). The East rays moved occasionally deliberately (as all did) but generally with exceptional rapidity, and often I was barely conscious that there was motion, it was so rapid—almost an instantaneous outbreak from base to upper end of circle. There at times great mass glows in east and occasionally west that were only suggestive of rays by their upper and lower edges being broken in a ray-like manner from the West looking like cloud. These generally had no motion and came and went instantly or slowly. Occasionally they had an upward motion, sometimes very rapid.

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17 Reprinted from Popular Astronomy, May, 1920, pp. 308-309.

18 Reprinted from Popular Astronomy, May, 1920, p. 307.

Color, whitish to faint yellowish—no blue, green, or red. East part the most active. Rays of light masses all round all the time, but except about 30° above or below the northern arch stars could be seen in every quarter at times and unusually near the horizon, indicating a clear atmosphere. The brightest light was in the East—next, at times, West, then North—least South.—*F. R. Welsh.*

52. *Pittsburgh, Pa.*—The auroral display of March 22 and 23 was by all odds the most magnificent ever seen in the vicinity of Pittsburgh It was possibly equaled in brightness by one which occurred on September 11, 1908, though the display on that date was much less imposing because the sky was illuminated by a full moon.

It was undoubtedly in progress during the afternoon, for as soon as darkness settled down the aurora was brilliant over all the sky except the extreme southern portion. At that time it appeared like patches of hazy cloud illuminated by yellowish light.

It is very difficult to describe a phenomenon so varied in its manifestations, and so dazzling in its beauty. From pictures I have seen of Artic auroras, this bore considerable resemblance to them. There were the same sinuous lines of brightness extending in a more or less horizontal direction near the northern horizon. From these as a base streamers extended up to the zenith, constantly changing in brightness from one point to another, thus giving the appearance of the waving auroral curtains so often mentioned in connection with the Arctic auroras. The general shift of the streamers was toward the west.

The convergent point of the streamers was in the meridian, and about 15° south of the zenith. Its position remained practically unchanged throughout the night. At the most brilliant period of the display it resembled the tip of a great umbrella of fire with luminous ribs extending in every direction. The colors were not very strong, mostly greenish yellow, though pink appeared at various times and in various parts of the sky.

By 9:30 the display seemed to be nearly over, but about 10 o'clock it recommenced with more vigor than before, and then came the most wonderful part of the whole display.

From the west appeared what seemed like a great brilliant comet with a very bright, strongly curved tail which gradually spread toward the northeast until it made a great arch spanning the whole northern sky. Under this arch it was darker than elsewhere. From the lower edge seemed to depend innumerable arrow-like points. Its color was white. Then began great pulses of light running from all the northern half of the horizon, and even from the south of the east and west points, to the radiant point. These succeeded each other with startling rapidity, so that almost the whole sky seemed to be a quiver with a weird light.

The whole effect was indescribably grand, and gave the beholder a feeling of awe as all this tremendous manifestation of electric forces proceeded without a trace of sound. This portion of the display lasted less than an hour, but the aurora persisted till daylight. At 3:30 a. m. it would have been considered an unusually fine aurora had we not had the display of the earlier part of the night. At this time it consisted of the usual bright auroral arch from which proceeded numerous streamers. It was still faintly active at dawn.—*Frank C. Jordan. (Allegheny Observatory).*

53. *Delphos, Ohio.*[19]—Probably the most spectacular aurora of recent years occurred on the evening of March 22. Though perhaps lacking some of the intense color of the display of March 7, 1918, it more than equaled it in the variety of interesting forms which it assumed.

It was first seen at 6:50 p. m., though probably noticeable before this. Even as early as 7 p. m. many streamers from the north and northeast reached the zenith and the colors of red and green were quite prominent.

The maximum of the display occurred about 9:10 p. m., when it assumed the curtain form in the east. Replete with color and shaken with great rapidity, it was bright enough to cast a dark and well-defined shadow. The dark upright bands in the curtain moved always from the east to west. * * *

The display lasted throughout the night and was still present to some extent the following evening. * * *—*L. C. Peltier.*

54. *Indianapolis, Ind.*—[At 7:30 p. m. there was] * * * a greenish white glow in the north which extended almost to the zenith. There were slight traces of bands from time to time and later a diffuse arch stretched from the star Gamma Andromedae in the west up toward the North Star and down to Arcturus in the east.

A few minutes before 9 p. m. a fine arch appeared low in the north with upright rays which brightened and faded as if they were rotating on an axis. The arch climbed higher in the sky and beams shot up from it and disappeared. Patches of red in the east and west appeared at various times. However, red areas of light were not as conspicuous as on former occasions. Soon the east was ablaze with greens and yellows which shifted to the north. Weird lights appeared like a clearing at twilight, after a storm. It was bright enough to read a watch dial and objects held close to the ground cast a distant shadow. About 9 p. m., radical pencils of whitish light shot from the northern horizon towards the zenith and a few degrees beyond, where they met between Jupiter (at present in the constellation Cancer close to the naked eye star cluster known as Praesepe), and the Sickle of Leo, silently "exploded" with much twisting and infolding, and dropped a canopy of yellowish white light, streaked with red and violet, over practically the entire sky. The whirling clouds of the "explosion" looked like cumulus lit up by lightning. A few minutes later, they were much fainter and more like wisps of cirrus set radically around the region of Leo and Jupiter. They remained for almost an hour in that part of the sky. The formation of the canopy occupied only a few seconds and the luminous region extended as far south as Sirius. Immediately after the "explosion," flickers and waves of light shot from the north to the focus in Leo within the fraction of a second, chasing each other with incredible speed. They seemed to skip the dark tracks of sky and light up auroral clouds beyond. Once or twice they appeared to generate new rays in dark spaces.

By 10:20 p. m., the region of Leo was dark and the light in the north appeared to be gathering strength for another display which consisted of a smaller arch with short upright rays, flickers and waves of light.

From 11:45 p. m., to 12:35 a. m., March 23 a band stretched across the sky from Castor and Pollux in the west toward Vega in the east and about 5° to 10° above the North Star. Soon it made a zig-zag like the letter Z (similar to the aurora of March 7, 1918) and drifted north to a position below the North Star. * * * [Flashes in quick succession from north to south at times] caused patches of light to shine in other parts of the sky.

1 a. m. lights again appeared in the north and broad radical streaks extended from the northern horizon towards the original focus, formerly in Leo, now occupied by Arcturus. * * *

1:30 a. m. a faint glow was still visible in the north and there was drifting haze below the bowl of the Big Dipper.

1:45 a. m. there was some haze near the North Star and faint broad streaks overhead.

1:50 a. m. broad, cloud-like patches appeared south and west of Arcturus.

2:30 a. m. a faint vertical bar of light was visible near Deneb in the Northern Cross.—*Russell Sullivan.*

55. *Abbe Meteorological Observatory, Cincinnati, Ohio (90th mer. time).*—The aurora borealis was first observed at 7:50 p. m. as an arch of light along the northern horizon. When first seen it was a diffused glare of white light without streamers, and extending about 30° above the horizon. During the following hour there appeared to be but little change, either in the position or size of the aurora, except that short streamers were occasionally visible.

At 8:55 p. m. streamers began to grow rapidly toward the zenith, first in the northwest and later in the north and northeast. Between 9 p. m. and 9:10 p. m. the streamers formed with great rapidity and became very bright but showed little color. The light extended a considerable distance beyond the zenith and for a few minutes the southern edge of the aurora formed an arc across the southern horizon about 45° high in the center, the southern cloudless sky appearing unusually dark. All of the streamers met at a point about 7° south of the zenith, the streamers from the north and northwest being very long, bright and well-defined, and those from the south comparatively short, poorly defined and of diffused light. The only pronounced color observed was a pinkish red glow in the northeast, which extended slowly up to the zenith and gradually died out.

After 9:10 p. m. the streamers disappeared even more rapidly than they had formed and there remained only patches of white glow in the upper portion of the sky extending about 30° in all directions from the zenith. Then followed a most remarkable display of flashing light through this field of patches. In contrast with the streamers these flashes moved like waves, and very rapidly, being in appearance somewhat like distant lightning and in movement somewhat like a mist or fine rain driven in a gale. By 9:30 p. m. the aurora had practically disappeared, but it reappeared again in the north before 10 o'clock and continued at midnight as a dim glare, showing some streamers.—*W. C. Devereaux.*

56. *Nashville, Tenn., March 22.*—About 9:05 p. m. * * * the northern sky showed yellowish green from near the horizon to a height of about 30°. Above that and almost to the zenith a red glow was observed. For a few minutes distinct bands or streamers of varying width extended upward, fan-shaped. These were less numerous and very faint by 9:15 p. m. A faint glow, maintaining the yellow color below and red above, continued for some time after this.

57. *Chattanooga, March 22.*—A beautiful aurora borealis was observed in the north from about 9 p. m. to 9:42 p. m. Streamers began shooting upward until five were observed, two pink and three yellow, reaching about 10° above the horizon with a quivering motion.

58. *Warren, Ark.*—From 9 to 9:30 p. m. [the aurora] had the appearance of rays of light similar to rays often seen when the sun is behind a small cloud, except they seemed perfectly straight and parallel and had no common center. The rays were very distinct and moved rapidly up. [A central shaft] * * * made its appearance at the horizon and in less than a minute it reached the Pole Star.—*J. L. Clegg.*

59. *Fort Worth, Tex., March 22.*—Aurora prevailed from about 8 p. m. to about 10 p. m., the sky was cloudy but light-way pulsations of a

[19] Reprinted from Popular Astronomy, May, 1920, p. 312.

pinkish and green shading and tintings flowed earthward [?] at intervals varying from one to three minutes, yet a constant glow was in evidence.

60. *Houston, Tex.*—On the evening of the 22d all telegraph wires were badly affected and could not be operated or operated with difficulty only. A flickering white light in sheet-form was observed in the northern sky at 10:30 p. m. which is thought to have been an aurora borealis. No arch or streamers were observed.

61. *Bismarck.*—An unusual auroral display was observed on the 22d from 9 p. m. until about midnight. Streamers were first observed in the north. These increased in number and extent until, at the time of greatest brilliance at 10:30 p. m., they issued from all points of the horizon. The longer streamers met at the zenith. There was a marked fluctuation in the brilliancy of the light.

62. *Rapid City, S. Dak., March 22.*—A most extensive and gorgeous display of the aurora was first observed about 7:30 p. m., local time, * * * as a whitish haze in the northern sky, gradually becoming denser and taking on a reddish hue. At 7:45 p. m. streamers or shafts of light began shooting upward resembling a strong searchlight when seen from a distance. At intervals the streamers were colored red and greenish. By 8 p. m. the aurora had spread from 90° to 270° azimuth, and the streamers appeared to converge at a point near the zenith, gradually extending until they reached the horizon in the south. About 8:15 p. m. the whole sky appeared to be filled with streamers of white light extending from the horizon from all directions, and meeting at the zenith, but evidently those in the south were overshot from the north that reached entirely to the horizon in the south. No arch was visible at any time. The display disappeared about 9 p. m. Some persons report that the display was repeated about 11 p. m. to midnight. * * *.—*H. N. Johnson.*

63. *Cheyenne, March 22-23.*—An aurora was observed at 11:30 p. m., March 22; it had evidently been on for some time as it was then in full glory. The colors varied from streamers of pink-red to streamers of yellowish-green, and fields of yellowish-green. Some of the streamers reached to zenith. A peculiar phenomenon was waves of light that seemed to originate at about altitude 20° and flicker upward to about an altitude of 80°. The display extended from approximate azimuth 140° to 230°. At 12:25 a. m. of the 23d it was faint but distinct.—*G. W. Pitman.*

64. *Albuquerque, N. Mex.*—[The aurora was] * * * a roseate glow, shading to a green light, with darting lights shooting far up into the sky * * * [lasting] from about 8 o'clock to nearly midnight.—*Albuquerque Morning Journal.*

65. *Kayenta, Navajo County, [northeastern] Ariz.*—* * * A low light bank appeared in the north at about 10 o'clock [12, midnight, 75th meridian time]. This gradually advanced toward the zenith, as bright streamers shot southward from it. From white settlers and Indians the writer could learn of no previous auroral display in this immediate section.—*Albert B. Reagan* (superintendent Marsh Pass Indian School).

66. *El Paso, Tex.*—An electrical display, probably aurora borealis, was seen by several parties shortly before and after midnight of the 22d. As described, there was a diffused light just above the horizon due north of the station, with streamers or jets of flame reaching at times several degrees above the horizon. One person said it looked as if there were a town or several oil wells on fire.

67. *Calgary, Alberta.*—* * * At 11 * * * I noticed quite a brilliant display of vertical streamers in the west. They extended, when first observed, from about 70° west of north around through to south to about 50° east of south, and could be traced to an altitude of perhaps 60°. After a few minutes they began to spread until they extended around the whole horizon making a very brilliant display, much the most brilliant I have ever seen. Besides the greenish light usually seen in such a display nearly all the colors of the rainbow were observed. A lot of blue or purple light was observed near the north and extending to the east. A little south of east an intense crimson was observed extending about 20° in latitude and lasting for some time. It was directly over the center of the city and looked very much like the reflection from a fire. This intense red seemed to extend only to the top of a low-lying cloud. Toward the end of the display it gradually paled and died out while there were a considerable number of vertical streamers still visible.

After the vertical streamers had spread till they extended around the whole horizon they became still brighter and spread upward until they formed a corona near the zenith. They finally met in the center but the light was more or less fused and one could not determine any sharply defined point of intersection. Assuming that Tenth Street NW. runs north and south, it was approximately 10° south and 5° west of the zenith. The diffused light formed a sort of brilliant ever-changing cloud about the zenith which kept breaking along a wavy line in a general north and south line, separating into two halves with a dark cleft between them and subsequently reuniting. Many of the lights which give the effect of a waving sheet of changing colored gauze suspended from the sky were also visible. * * * They were mostly to the south of me.

* * * The light which caused the vertical streamers seemed to be extending in waves vertically upward from the horizon, the waves following each other in very rapid succession, four or five being visible simultaneously, one above the other. The waves were not separated by dark spaces; they were merely points of intensified light. These waves extended across many streamers or were synchronous on all streamers in one's vision. This effect of ascending waves of light was most noticeable when looking toward the southwest, which was about the center of the display all through, and was not noticed until toward the end of the display but while the light was extremely bright. The light was sufficient to light the earth considerably, but I believe it would not have been sufficient to enable one to read.

By 12 o'clock the display had died down until it was not worthy of special notice. * * *—*Owen Bryant.*

68. *Brewster, Wash.*—[The aurora] reached from due east to due northwest; also to zenith. Western edge colored red-orange-green, very bright and lasted until about 3 a. m.—*Wm. Saul.*

69. *Spokane*, March 21, 22, 23.— * * * [The] most brilliant display at Spokane occurred at 10 p. m. (120th meridian), March 22, in the form of intensely luminous beams radiating in all directions from a point in the zenith; the first indications some observers, at this place, had of this display were noted in the sky *south* of Spokane's zenith. This aurora and all indications of it had disappeared from Spokane by the morning of March 23. * * *—*C. Stewart.*

70. *Seattle*, March 22.—The aurora borealis was first observed as early as 8 p. m. It became a brilliant display by 10 p. m. and continued till past midnight but becoming dimmer after 11 p. m. and apparently shifting to westward.

When brightest, the luminous arch spanned more than the northern half of the sky. Light rays converged to a focus somewhat south of the zenith and then diverged. At times patches of light flashed about 45° south of the zenith. At about 10:15 p. m. both in the northwest and the northeast the sky was rose-colored. After this the pulsation of streamers was more pronounced. The general color was white light to a very pale yellow with a suggestion of green. Telegraph companies and the cable office reported serious interference in transmission of messages owing to the earth's disturbed condition. This was true to a less extent on the night of the 21st and the night of the 23d.

71. *Yakima, Wash.* (120th mer. time).—The aurora [appeared] * * * as early as 7:30 p. m. on the night of March 22. About 9:45 p. m. a wide arc stretched across the zenith from a little south of due east to a little north of due west. At 10 p. m. there was a broad, curving arc in the north, with rays extending up from it, which a few minutes later extended beyond the zenith, converging to a well-defined point. A little later, most of the rays faded out for the greater portion of their length, leaving a particularly brilliant portion near the zenith. All this was colorless, except for a reddish tinge in the east, and some reddish streaks in the northwest. At 10:10 p. m. the rays reappeared for their whole length, and became much more pronounced, successive waves of light passing from the arc near the northern horizon up to the zenith. The red streaks in the east and west became more noticeable. By 10:25 p. m. the bands were farther from the northern horizon, and the rays much dimmer and more diffuse, although waves of light still occurred. The area between the arc and the horizon appeared darker than any other portion of the sky, as did a part of the sky south of the eastern part of the light area. In both cases stars were observed shining in these areas.—*E. J. Newcomer.*

72. *Walla Walla, Wash., March 22.*—I first noticed the aurora about 9:15 p. m. as a bright band of light about a quarter of the distance from the horizon to the zenith, stretching from northwest to northeast. Closer observation showed a very bright patch of sea-green light rather low down on the horizon and a little later a dim rose-colored patch to the northwest. After a time long streamers began to form and extended from the patch of green in the north well up toward the zenith: these were almost steady at first but began to waver and gradually grew dim, finally ceasing altogether. A few minutes later the whole northern sky was lighted up with intermittent flashes of light of greenish-white cast, so bright as in some cases to blot out the stars. These flashes shot up from the horizon with great speed and looked like green vapor being blown by the wind, the green at times changing to copper color. * * * There was still a bright greenish light to the north at 11 o'clock when last observed.—*R. H. Desmond.*

73. *Boise, Idaho.*—In the March number of the Bulletin I note a request for descriptions of the aurora of March 22. In response thereto, I submit the following:

* * * At about 8 o'clock * * * [there was] a faint bluish-green glow down on the northern horizon.

* * * The glow gradually increased in brightness and also in extent. In about an hour, it had extended to about 80° of the horizon and about a height of 35° above the horizon. At about this time the streamers became visible, some of them eventually reaching as high as 45°. By 10 o'clock the spectacle had reached its maximum intensity and beauty. At about 11:30 I observed a reddish tinge to some of the streamers, although it was very faint—the predominating color throughout being the bluish-green. Some of the streamers appeared to stream out from the horizon, others seemed to appear almost simultaneously their whole length. At about this hour (11:30), I observed a sort of radiation from the base of the streamers upward. This radiation appeared as a dim, but regular, arc of comparatively bright light which arc was parallel to the arc of the aurora. This arc passed rapidly from the base to the limits of the aurora, occupying about one second to

cover the distance. There was a rapid succession of these "radiations" which varied greatly as to brightness, and gave the effect of enormous tongues of flame leaping upward. At no time during my observation was this "radiation" very bright, but its peculiar nature made it quite conspicuous.

There was considerable variation in the place of greatest brightness along the horizon. At one time, I observed that that the west end of the display was much more brilliant than the rest; at other times, the brightest part was the east end. For the most part, however, the center of the illuminated area was the brightest. I continued my observations until well past 12 o'clock, and at that time the glow was as brilliant as ever.—*Charles W. Fanckboner.*

74. *Fresno, Calif.*—An aurora was observed here from 10:45 p. m. to 11:15 p. m. of March 22 by Roy E. Miller, editor of Associated Growers' Magazine. Note of his observation was made in our records at the time and I find it to be the first and only occurrence of this phenomenon here that has been entered in our records.

He reported the sky as partly overcast at the time with a bank of dense dark cloud [the characteristic dark segment of clear sky (?)] with clear-cut margin lying along the northern horizon, which seemed to heighten the contrast with the reddish, white, and violet streamers of the aurora above. Our latitude is 36° 43'.—*C. E. Bonnett* (U. S. Weather Bureau).

We wish to extend our grateful acknowledgments to all those who sent their descriptions to us, and to the numerous U. S. Weather Bureau observers who took the pains to enter accounts of the aurora in their meteorological records. In addition to those whose names appear at the end of the published descriptions, notes were received from the following: Robert H. Allen (West Roxbury, Mass.). F. Z. Hartzell (Fredonia, N. Y.), Charles W. Leng (Staten Island, N. Y.), L. B. Bonnett (Elizabeth, N. J.), J. W. Harshberger (Philadelphia, Pa.), T. P. Irving (Notre Dame, Ind.), W. S. Gorton (East Orange, N. J.), H. G. MacMillan (Greeley, Colo.), E. B. Scott (Dahlgren, Va.), S. S. Visher (Bloomington, Ind.), Charles C. Hopkins (Rochester, N. Y.), A. T. Jones (Northampton, Mass.), George D. Rogers (Gloucester, Mass.). Published accounts not excerpted or reprinted here are to be found in *Popular Astronomy*, April and May, 1920, vol. 28, pp. 248, (North Scituate, R. I.), 310–311 (Chestertown, Md., Wellesley, Mass., Brooklyn, N. Y.).

TELEGRAPH AND RADIO EFFECTS.

It is interesting to note that there were numerous references to telegraphic troubles, especially during the periods of maximum in the magnetic storm. Thus, trouble was felt between Switzerland and France in the afternoon of March 22 and at the same time (early morning and till about 3 p. m., eastern standard time) in the United States and Canada, which led some people to be on the lookout for the aurora. The Atlantic cable service was adversely affected.

Radio communication, strange to say, is usually but little affected during auroras. The following note from Gloucester, Mass., is of interest in this connection:

The 10 o'clock radio time signals from Arlington [Va.] and a message immediately afterwards were listened to from a small antenna. No unusual static discharges were noticed, but the strength of the received signals varied enormously, from almost nothing to seemingly more than usual loudness. The periodicity was not regular, but slow enough to permit futile attempts at better adjustment during the minima, and the changes in strength were not abrupt.—*H. G. Dorsey.*

This was at the time of greatest intensity of the whole display, and there were at least three brilliant auroral curtains between Arlington and Gloucester.

BRIGHTNESS OF THE LIGHT.

The brightness of the aurora was the subject of special comment by many observers. The amount of light was estimated to be "as bright as twilight 10 minutes after sunset on a clear day" (at Charlotte, N. C.), or equalling the brightness of the northwestern sky half an hour after sunset, or to cast a light equal to that of the moon in first quarter, or even full. Some mention how the brilliance of certain portions of the display would cast well-marked shadows and also how it was possible to read a watch.

The light at times may have been sufficient for reading. Fortunately, Prof. Joel Stebbins made some actual measurements of the intensity of the light, at Urbana, Ill.:

The auroral light interfered with our photometric observations at the telescope that evening, because of the variable bright background for any star. A few rough measures gave the result that a patch of auroral streamer equal in apparent area to the full moon gave about as much light as a second magnitude star. This refers to the blue light which most affects the photo-electric cell, which is not very different from the photographic plate in color sensitivity.[20]

Some photographs were obtained, at various places, though the movement of the streamers makes it difficult to get anything sharp without special plates.[21]

THE END OF THE DISPLAY.

The best part of the auroral display ended with the maximum phase of the magnetic storm at 2 a. m. eastern standard time (7^h G. M. T.), but there was an unusual aurora during the following two hours, until the magnetic storm practically ended at $8^h 50^m$. The aurora was last seen at dawn at several places in the eastern United States; and Mr. William Saul at Brewster, Wash., says that it "lasted till about 3 a. m." (11^h, G. M. T.). It seems probable that the aurora continued throughout the 23d, for it was visible again at dark that night.

The southernmost reports in different sections were Washington, D. C., Fort Worth, Tex., and Seattle, Wash. On the following night, March 24–25, people at northern stations observed a normal faint aurora, while a few in middle latitudes saw an unusual spot-light display, which would last for a few minutes, then fade away in a few seconds, only to reappear as suddenly. The behavior of these spots was not unlike that of the luminous clouds of two nights before, but the absence of streamers made the display look peculiar. A discussion of some angular observations made on these spots from widely separated places is published below, on p. 392. There are scattering reports of a faint aurora on the night of March 25.

AURORAS ASSOCIATED WITH PREVIOUS AND SUBSEQUENT PRESENTATIONS OF THE DISTURBED AREA ON THE SUN.

The great sunspot group responsible for this four-day aurora * * * was a revival of a similarly extended group of spots of large area observed from January 21 to February 3. At the next rotation, February 17–27, this group appeared as an insignificant small spot and dots amidst extensive faculæ. But the magnetic elements began to be disturbed during this second rotation of the spot group on February 16–17.—*A. L. Cortie.*[22]

Mr. C. S. Ling, of the United States Weather Bureau aerological station at Drexel, Nebr., observed an aurora from 1:55 to 2:22 a. m. February 17, and Mr. W. A. Bentley, of Jericho, Vt., an aurora on February 19–20.

By the middle of April the rotation of the sun brought the disturbed surface again into a position to affect the earth.

* * * On the 16th of April a medium-sized spot became central. It was probably one of the six spots of the before-mentioned group. It was followed by a small spot some 200,000 miles after and also central about two days later. It was possibly another remnant of the old

[20] Science, May 14, 1920, pp. 485–486.
[21] See Popular Astronomy, May, 1920, plates 13–15. L'Astronomie, Avril, 1920, plate 2, contains three pairs of photographs of the aurora of Oct. 4, 1919.
[22] Nature (London), April 1, 1920, p. 137.

group, but too small to be of any consequence. It had disappeared by the 19th. * * * on the morning of the 17th telegraph operators noticed a disturbance.—*E. D. Roe, jr.*[23]

Mr. Owen Bryant reports that the "aurora was bothering the wires again on the morning of April 20 [at Calgary]," but the weather did not permit him to observe any display. Auroras were reported as seen in New England on the nights of April 14, 16, 17, 18, 19, and at Jericho, Vt., only, April 20–22. The aurora of the 16th was also seen at Ottawa, Canada, that of the 17th at Plainfield, N. J., and that of the 19th extensively throughout New England, and, possibly, through a rift in the clouds at Washington, D. C.

On the following presentation, a faint aurora was observed at Washington, D. C., on the night of May 9, and another by Mr. W. A. Bentley at Jericho, Vt., and by Prof. G. R. Wieland at New Haven, Conn., on the night of May 15–16. Other auroras have not been reported, and from the waning character of the displays at successive rotations of the sun it appears that the unusual solar activity has ceased.

We shall be fortunate if we ever see the equal of this marvelous aurora. Such are rare indeed anywhere in middle latitudes. (See Table 1.) Four potential auroras may pass unnoticed in the daytime, in the latter half of night, or behind the clouds, for each one that a person can see on a clear evening. We can count only five such great world-wide auroras during the past five years embracing this unusual sunspot maximum. Our turn is not likely to come again for 20 years.

TABLE 1.—*A list of the principal auroras from 1914 to 1920, inclusive.*[1]

Year.	Greatest.	Great.	Unusually brilliant.
1914	None	None	None.
1915	June 16–17	None	[Oct. 6–7 (Iceland).] [Nov. 14–15 (Iceland).]
1916	Aug. 26–27	None	None.
1917		Aug. 9–10; Dec. 16–18	Jan. 4.
1918	Mar. 7–8	Aug. 15–16	May 15–17.
1919	Aug. 11–12	Oct. 1–3	Feb. 27–28. May 2.
1920	March 22–23		

[1] Many of these displays are described in the MONTHLY WEATHER REVIEW for the years indicated.

NOTE ON THE HEIGHT AND LOCATION OF THE AURORA SPOTS AND BELT OF MARCH 24, 1920.

By CHARLES F. BROOKS and C. LEROY MEISINGER.

[Weather Bureau, Washington, D. C., May 10, 1920.]

In comparing the notes of various observers of the aurora of the night of March 24–25, it appears that some of the spots and patches observed in various places were identical, but that they appeared in various parts of the sky to the various observers. This makes it easily possible to calculate the altitude of the aurora and determine its location. For example, a certain spot was simultaneously seen from South Hadley, Mass., Concord, Mass., Rochester, N. Y., and Washington, D. C. Prof. Anne S. Young at South Hadley saw it in the southwest at an altitude of about 15°, Mr. Milroy N. Stewart at Rochester saw it in the southeast at about the same elevation, and at Washington it was observed in the northeast-by-north at an elevation of 35° to 40°. While Mr. Fred A. Tower at Concord certainly saw the same spot, the reported elevation seems to have been estimated somewhat too large, it being reported as 40°. These lines meet in an area over southeastern Pennsylvania and central New Jersey, and trigonometrical calculation shows that its height was about 140 kilometers (87 miles).

Again, the May, 1920, issue of *Popular Astronomy*, pages 307–312, gives some interesting photographs and reports. One of these photographs, taken about midnight, March 24, in Brooklyn, N. Y., shows an auroral spot in the southeast together with several star trails, among which the most conspicuous were those of Mars and Spica. This spot was observed in Washington, between east by south and east-southeast within a few degrees of the horizon. Measuring on the photograph made at Brooklyn it is possible to determine with fair accuracy the angular altitude of the auroral spot at that place, and its center is found to be about 13°. If lines are drawn toward the southeast from Brooklyn and toward a point between east-by-south and east-southeast from Washington, it is found that they intersect in the ocean about 320 km. from Brooklyn and 470 km. from Washington. Using the Brooklyn elevation, we find the altitude of the spot to be about 120 kilometers (73 miles).

Another case, taken in part from the reports in *Popular Astronomy*, is that of an observer in Ann Arbor, Mich., reporting a bright patch in the south about 20° above the horizon at 11 p. m. 90th meridian time. From Washington, this spot appeared in the west-by-north about 7° above the horizon. Calculation shows it to have been about 330 km. south of Ann Arbor, and 610 km. west-by-north of Washington at a height of about 130 kilometers (81 miles).

All these values being in very good agreement, it is reasonable to assume that the display was taking place at that general elevation; or, to take the mean of the three calculations, 130 kilometers (81 miles). Making this assumption as to the altitude, it is possible to locate other spots which were observed from Washington. Such a one was seen in the northwest to northwest-by-west or west-northwest at about 9:45 p. m., appearing as lenticular in form with its lower edge at an elevation of 18° and its upper at 23°. Assuming this to have been actually a flat base and its elevation 81 miles, we find that the more distant edge must have been 400 km. from Washington and its nearer edge about 300 km. This would place it over east central Ohio and western Pennsylvania. Mr. H. D. Pallister, writing from eastern Kentucky, says:

"I also saw the aurora on March 24 about 9:30 p. m. (C. S. T.?) at Wolfpit, Pike County, Ky., and watched it for over one-half hour. As seen here it consisted of undulating flashes of white light radiating from a general northerly direction. The flashes would occur at intervals growing brighter and then die out for a time."

The two spots over eastern and western Pennsylvania early in the evening, grew into a belt stretching from a few hundred miles out to sea, across northern Virginia to southwestern Ohio. Although the belt seemed to move slowly, it was traveling southward at about 60 miles an hour.

THE PHYSICS OF THE AURORA.[1]

By W. J. HUMPHREYS.

[Abstract.]

We are fortunate in having collected in one book practically all that is known concerning the aurora:

[23] Science, May 14, 1920, p. 486.

[1] Presented before American Meteorological Society, Washington, D. C., April 22, 1920.

"Bericht über die neueren Untersuchungen am Nordlicht," by L. Vegard.[2] This is a very complete bibliographic and mathematical discussion of the subject. The height of the aurora has been determined accurately by simultaneously photographing the same aurora from two stations against a common background of stars, and measuring the parallax obtained. The lower limits of the aurora vary from perhaps 85 kilometers to 170 kilometers, with two well-defined maxima, at 100 and 106 kilometers. The tops extend to heights exceeding 300 kilometers. The magnetic effects accompanying auroras show that they are owing to moving electrons, and their coming most at times of maximum sunspots shows connection with solar disturbances. The electrified particles make the luminosity. Most of the spectral lines are nitrogen lines, but the most prominent one, the "auroral line" is a greenish line of wave length not fitting any known element. The nearest line is a krypton line, but the other krypton lines are not present. [See abstract immediately following this.]

The aurora seems to be caused by electrified atoms discharged from an active area on the sun, which atoms are in part intercepted by the earth's magnetic field and guided toward the magnetic poles. As the particles follow the lines of force in the earth's magnetic field, the visible auroral streamers, which are produced by their action on the atmosphere, are practically straight lines, and therefore produce the coronal or ribbed-dome effect observed whenever an auroral arch with streamers passes through the observer's magnetic zenith.[3] The dark hole (frequently observed at the center of the corona) is the perspective effect produced on looking along the streamer lines.

The electrons have a penetrating power which can carry them through the atmosphere down only to an altitude at which the atmosphere reaches a certain density. Since the particles that form the usual aurora seem to have about equal penetrating power, the under limit is sharply defined and at about the same altitude.

When the aurora reaches a certain degree of intensity, electrical discharges take place, and first where the resistance is least, namely, in the strongly ionized air at its lower limits. The breakdown thence spreads rapidly upwards giving the impression of a rapidly upward moving wave of light.[4]

The variations in the intensity of the aurora probably depend on the varying abundance of arriving particles from the sun, as well as upon the position of the bright spots relative to the observer.—*C. F. B.*

GENERAL AURORAL ILLUMINATION OF THE SKY AND THE WAVE-LENGTH OF THE CHIEF AURORA LINE.

By V. M. SLIPHER.

[Reprinted from Science Abstracts, sec. A, Sept. 30, 1919, §1165. Abstracted from Astrophys. Jour. **49**: 266-275, May, 1919.]

During the past three and one-half years about a hundred spectrograms have been made at the Lowell Observatory of the night sky, and every one of these has recorded the chief aurora line. The spectrograph, therefore, gives direct evidence of the existence of permanent auroral illumination of the sky. The close dependence of displays of aurora upon sun-spot activity suggests that there are variations in the intensity of this general illumination due to the aurora. A preliminary determination of the wave length of the aurora line indicated a longer wavelength than the commonly accepted value λ5571. Further measurements on plates obtained with a higher-dispersion spectrograph gave a mean value for the wave length of λ5578.05. The plates showed clearly that the line falls well to the red side of the strong solar line λ5573.075, and so the value λ5571 must be considerably in error. Stark [Abs. 745 (1918)] has put forward the view that the origin of the chief aurora line is probably the nitrogen pair λλ5560, 5565, but the new value obtained for the wave-length renders this view quite inadmissible.—*A. W.*

[2] Jahrbuch der Radioaktivität und Electronik, 1917, vol. 14, pp. 383-465, 7 figs., 5 tables

[3] Cf. *Science*, May 14, 1920, N. S. vol. 51, p. 485.

[4] See the more detailed discussion by S. Chapman, "Electrical phenomena in the upper atmosphere;" reprinted in *Sci. Amer. Suppl.*, Sept. 27, and Nov. 29, 1919, pp. 198. and 323; abstracts in *Nature* (London), June 19, 1919, p. 311, and MONTHLY WEATHER REVIEW, Dec., 1919, **47**: 879.

AURORA OF MARCH 4-5, 1920.

[Reprinted from Nature (London), May 13, 1920, p. 337.]

A short article in our issue of March 11, page 56, describing a magnetic disturbance which occurred on March 4–5, mentioned that aurora had been observed at Aberdeen on March 4, but considerably earlier than the commencement of the disturbance, and so presumably not directly connected with it. This seems to have been the only observation of aurora in this country on either March 4 or 5. A letter, however, which we have received from Prof. A. S. Eve, of Montreal, mentions a brilliant aurora as having been observed there between 1 a. m. and 2 a. m. G. M. T. on March 5, and so synchronous with the magnetic storm. Commencing with isolated patches, the aurora appeared for a short time in the form of an arc and ended in a curtain display. This incident leads Prof. Eve to inquire whether there is in existence "an organization for recording, with accurate timing, auroras in both northern and southern hemispheres, and, if so, where can the records be obtained?" So far as we are aware, no such records exist. The question seems to merit the consideration of the recently instituted Section of Terrestrial Magnetism and Electricity of the International Geodetic and Geophysical Union.

AURORAS OF 1919 IN THE UNITED STATES.

By HERBERT LYMAN.

[Weather Bureau, Washington, Aug. 31, 1920.]

The following tables of auroras observed in the United States during the year 1919 are based on two sources of data. First, the original monthly meteorological reports of all regular Weather Bureau stations; second, the published "Climatological Data," compiled each month by the several section centers under the supervision of the Climatological Division of the Bureau. The section reports are not, however, all uniform in the matter of listing "Miscellaneous meteorological phenomena" (under which auroras are classed) so that the tables here presented are not all-inclusive. But while there were a few instances where no record was kept of auroral displays, in the main the tables below are reasonably accurate.

Upon examining table 1, one is rather surprised to note the large number of days on which auroras were seen. Thus for the entire year there were 171 auroral displays reported—an average of one aurora to every

TABLE 1.—*Number of States*[1] *in which auroras were reported as observed on any given date in 1919.*

1919.	Jan.	Feb.	Mar.	Apr.	May.	June	July.	Aug.	Sept.	Oct.	Nov.	Dec	
1	1	1	1	1	4	1		1	1	11			
2	1		1		10	2		2	2	5	1		
3	2				6					2	1		
4	4	1			2	2		1		2			
5	2		1		4						1		
6		1	2	2	1			1					
7			1					1		2			
8	1		1		1				1	1			
9	1			2					1				
0	1								1	1	1		
11								8			1		
12			1		1	1		1			1		
13	1	3	1							1			
14					1			1				1	
15			1						5	3	1	1	
16		1	2	1	2				1	1	3		
17	1		1		1			1	3	5	2		
18				3	1			2	7	1		1	
19		1	3	3	1		1	1	8		1	1	
10		4	6	2	2			1	5		1	1	
21		4	7	4	1			1	2		1		
22	1	4		4	1	2			2	5			
23		1	1	1				1	7	6	2		
24			1	1	1	1		1	10	1			
25			2	1	1	2		1	5				
26		4	2		1			1	3	2			
27		8	3	1		1		1	1	1			
28	2	7	2			1		1		1			
29									1	3	1	1	
20	1		1						1	1			
31	3				1					2			
Number of days with auroras	14	13	21	13	20	9	1	19	20	21	14	6	171

[1] For the purposes of this table, the District of Columbia is regarded as a State.

2.1 days throughout the year, taking, of course, the country over. In point of seasonal distribution September seems to have been the most favored month, while July was the least.

Table 2 is designed to give a further idea of the seasonal extent of the auroras observed.

Thus no less than 28 such displays were seen in at least four States at one time, while three displays were witnessed in 10 States simultaneously.

Table 2 also shows the number of days on which auroras were seen. In this connection it is interesting to note the distribution (in point of time) of the auroral displays. The first quarter of the year had a total of 48, the second quarter, 42, the third quarter, 40, and the last quarter, 41. March and October had the largest number of displays—21 each. July had the least—only one.

TABLE 2.—*Number of auroras in 1919, arranged by State groups*

Number of States	4	6	8	10
Number of auroras	28	13	6	3

It is not practicable to go into any details of these auroras here, but any one wishing to study accounts of of the more prominent ones may apply to the Weather Bureau library for information.

A SIMPLE EQUATION OF GENERAL APPLICATION FOR THE NORMAL TEMPERATURE IN TERMS OF THE TIME OF DAY AND THE DAY OF THE YEAR.

By FRANK L. WEST, Ph. D.,[1] Physicist, Utah Agricultural Experiment Station.

(Logan, Utah, July 16, 1920.)

SYNOPSIS.

The following empirical equation

$$T=\frac{Ma}{2}+\mathrm{Va}\cos t+\frac{My}{2}\cos\theta$$

represents the normal temperature as a function of the time for the United States except for the arid West, where we must add the term $\left(\frac{\mathrm{Vv}}{4}\cos t\cos\theta\right)$. The constants are the mean annual temperature, the range of the annual march, and the range of the daily march, and are obviously easily obtained from the Weather Bureau data for the place desired. The mean error for the arid West was 2.75° F. and it is less for the rest of the United States. The equation simply assumes that the annual and daily march of temperatures are simple cosine functions.

DISCUSSION.

It is generally known that the air is alternately warmed during the day and cooled at night and also warmed in summer and cooled in winter. The normal temperature then is a periodic function of the time with a twenty-four hour and an annual period. The writer[2] obtained an empirical equation for these changes with the aid of the Fourier analysis and called attention to the fact that these series, made up of cosine terms, converged so rapidly that the omission of all of the terms except the first two had only a slight effect on the result. Professor Marvin[3] also found that in some regions the annual march of temperature is very approximately represented by a simple cosine curve. Its equation would therefore be

$$Md=Ma+\frac{Va}{2}\cos t \tag{1}$$

where Ma represents the mean annual temperature;
Md represents the mean daily temperature for the day t;
Va represents the annual range in temperature or the difference in the mean daily temperatures of the hottest and coldest day of the year, and
t represents the time of the year, zero of time being on the hottest day of the year or at the maximum of the curve.

[1] The writer received helpful suggestions from Dr. Willard Gardner, Associate Physicist, Utah Agricultural Experiment Station.

[2] West, Frank L., Edlefsen, N. E., and Ewing, Scott—"Determination of the Normal Temperature by Means of the Equation of the Seasonal Temperature Variation and of a Modified Thermograph Record." (*In* Physical Review, Vol. 14, No. 3 (1919). Also *in* Jour. Agr. Rsch., Vol. 18, No. 10 (Feb., 1920). *Abstract in* MONTHLY WEATHER REVIEW, Dec., 1919, 47:877.

[3] "Marvin, C. F.—Are Irregularities in the Annual March of Temperature Persistent?" (*In* MONTHLY WEATHER REVIEW, Vol. 47, No. 8, p. 544 (1919).
This paper indicates that for a section of the northeastern United States represented by New England and the States of New York, Eastern Ohio, Pennsylvania, Maryland, and part of Virginia, the annual curve of temperature is well represented by a single cosine curve. Elsewhere in the United States two terms are in general required with an amplitude of the second term of 1 to 2 or more degrees. In the arid southwest later studies show three terms are necessary for consistent accuracy.
The literature on the subject is best reviewed in the two following articles: Pernter, J. M.—"Present Status of Our Knowledge of the Causes of the Diurnal Changes in Temperature, Pressure, and Wind." (*In* MONTHLY WEATHER REVIEW, Vol. 42, No. 12, pp. 655-665 (1914).
Talman, C. Fitzhugh—"Literature concerning Supposed Irregularities in the Annual March of Temperature." (*In* MONTHLY WEATHER REVIEW, Vol. 47, No. 8, pp. 555-565 (1919).

The curve representing the twenty-four hour temperature change (thermograph record) modifies its shape gradually each day, flattening out (to an extent depending upon the locality) as winter approaches. During the summer when the heat is being received fast, one would expect the rise in temperature to be greater for the same time-interval than in winter, and thus in arid sections it is found that the daily variation in temperature is nearly twice as much in summer as in winter. However, for regions of small rainfall the ratio of the hourly temperatures to the mean daily temperature (Fahrenheit) is nearly constant whatever day of the year is selected, e. g., the ratio of the maximum to the mean is approximately constant for all days of the year. Irregularities will be mainly caused by storms and enough ratios must be taken in obtaining this constant to eliminate these. The plot showing the percentages of the mean for each hour is approximately a cosine curve and has the following equation:

$$P=100+\frac{Vp}{2}\cos\theta \qquad (2)$$

where P represents the per cent of the mean that the hourly temperature has, Vp represents the total variation or range in the per cent for the 24 hours, θ represents the time of day expressed in degrees.

Since the hourly normal would be the per cent of the mean daily multiplied by the mean daily temperature, it would be equal to the product of equations (1) and (2), giving

$$T=P\ Md=\left(100+\frac{Vp}{2}\cos\theta\right)\left(Ma+\frac{Va}{2}\cos t\right) \qquad (6)$$

This equation will give fairly accurate results for normals of the arid regions, but falls down in humid sections because as winter approaches the daily range does not diminish as fast as the mean daily does, thus making this constant really a function of the time, or, in other words, not a constant at all. It is not quite rigorously true in the arid regions because if it were the range and the temperature would have to vanish together, i. e., when in winter the mean daily temperature reached 0° F. there would have to be no daily range but a constant temperature for the 24 hours. From 20° F. up it works very satisfactorily, however, and in the arid west of this country probably 95 per cent or more of the days of the year have mean daily temperatures higher than this; hence, it gives satisfactory results for this part of the country.

Another somewhat similar equation will now be derived which fits the facts still better and is more general in application.

The normal thermograph record for a particular day is approximately a cosine curve. In fact, it will be shown later that if the time or angle be counted from the maximum and the minimum on the curve, that the following simple equation will fit the facts even better than the corresponding one fits the annual range in temperature:

$$T=Md+\frac{Vd}{2}\cos\theta \qquad (3)$$

where T represents the temperature at the time of day θ, the hours being expressed in degrees,

Md represents the mean daily temperature,

Vd represents the daily variation or range in temperature for that day.

Vd, or the daily variation in temperature, is also a periodic function of the time, the period being one year and the maximum occurring in the summer, and for the reasons indicated earlier in this paper.[4] The difference between the daily range in summer and in winter is from 0 to 5 degrees for points in the United States outside of the arid West and about 10 degrees for the latter section. The following equation represents fairly well these facts:[5]

$$Vd=My+\frac{Vv}{2}\cos t \qquad (4)$$

where Vd represents the daily range for the day t,

My represents the average daily range for the year,

Vv represents the difference between the range in summer and winter.

Substituting equations (1) and (4) in equation (3) the following equation is obtained for the normal temperature T on the day t and for the hour θ:

$$T=Ma+\frac{Va}{2}\cos t+\frac{My}{2}\cos\theta+\frac{Vv}{4}\cos\theta\cos t \qquad (5)$$

This equation is a general one and the constants for a particular city can be obtained in less than five minutes' consultation of the U. S. Weather Record for that place. For all places except very arid sections the last term is zero and the equation is thus still simpler.

This equation rests on the assumption that the annual march of temperature can be represented by a single cosine function, that the daily march can be represented by a single cosine function, and that the change in the daily range with the season can likewise be represented by a cosine function. Although there is a physical reason for each of these periodic changes, yet the above equation is purely empirical and meritorious only to the extent that it fits the facts and is simple of application. These marches of temperature are not exactly cosine functions for the curves are not quite symmetrical, the number of days between the minimum (about Jan. 15) and the maximum (about Aug. 1) for the year counted in the spring being usually somewhat more than when counted in the fall. Likewise, the time-interval between the minimum in the morning (about 6 a. m.) and the maximum (about 3 p. m.) is about nine hours measured in the morning, while it is fifteen hours when measured through the night.[6] This error, however, may be largely eliminated by making the curve pass through both the maximum and the minimum in the process of converting the days and hours into degrees before substituting in the equation, e. g., for Salt Lake City, or most any city of the same latitude, an hour in the morning represents 20°, $\frac{180}{9}$, while in the evening it stands for only 12°, $\frac{180}{15}$; and a day in the spring of the year 0.9 of a degree, and one in the fall 1.1°. Thus, starting time when the temperature is a maximum (3 p. m. for Salt Lake City) the angle corresponding to 9 a. m., which is three hours

[4] "Climatology of the United States," pp. 94-97 (*In* Bulletin Q, U. S. Weather Bureau)

[5] Lack of being an exact cosine function is not at all serious because this term is negligible in most regions. See fourth column of Table No. 1. Where it is appreciable it followed the cosine law very well.

[6] By replacing cos t by $\cos\left(\frac{2\pi t}{365}+10\sin\frac{\pi t}{365}\right)$ and cos θ by $\cos\left(\frac{2\pi\theta}{24}-30\sin\frac{\pi\theta}{24}\right)$, the equation will fit the facts better, but it becomes now nearly as involved as the Fourier series equation, but still has more readily determined coefficients.

after the minimum, would be $180+3\times 20=240$ rather than $\frac{360}{24}\times 15=225°$, and 5 a. m. would be $180-12=168°$, 2 p. m. $=360-20°$, and 4 p. m. $=12°$. The lack of symmetry of these curves, therefore, can be largely eliminated by counting the time from the nearest maximum or minimum of the curve.[7]

The equation for Salt Lake City becomes

$$T=51.5+22.2 \cos t+10 \cos \theta + 2.55 \cos \theta \ t,$$

the addition of the first two terms giving the mean daily temperature for the day t, and the sum of the four terms the normal hourly temperature for the hour θ on that day.

Assuming that the normal hourly temperatures for the month represent the normal thermograph record for the 15th of the month, these monthly values were obtained from as many U. S. Weather Bureau stations as possible and checked against the values obtained from the corresponding equation for that city for the 15th of each month. The mean error ± for Salt Lake City was 2.7°, for Portland, Oreg., 2.2°, for San Francisco, 2.4°, for Chicago, 2.5°, for New York City, 2.8° F., for Memphis, Tenn., 2.2° F. Using the first two terms only and thus obtaining the mean daily temperatures the errors were 1.37°, 1.4°, 1.6°, and 1.2° F., 2.0°, and 0.5° F., respectively, in this determination of mean daily temperatures.

TABLE 1.—*Constants for the equation* $T=Ma+\frac{Va}{2}\cos t+\frac{My}{2}\cos\theta+\frac{Vv}{4}\cos\theta\cos t$ *for various cities of the United States.*

City.	Mean annual temperature= Ma.	Range of the annual march $+2=\frac{Va}{2}$.	Average daily range $+2=\frac{Mv}{2}$.	Range of daily range $+4=\frac{Vv}{4}$.	Average daily variability of temperature.
East Atlantic States:					
Boston	49	23	8	0.5	5.6
Albany	48	25	8	1.0	....
Buffalo	47	23	6	0.7	....
New York	52	25	7	0.7	....
Washington	55	22	9	6.0	4.8
Atlanta	61	16	8	0.7	4.1
Jacksonville	69	14	8	0.5	3.5
Central States:					
Little Rock	62	20	9	1.0	....
New Orleans	69	18	7	0.5	3.3
Galveston	70	16	5	0	....
Bismarck	40	32	11	1.0	6.2
Milwaukee	45	25	7	0.5	....
Omaha	50	28	9	1.0	....
St. Louis	56	24	8	1.0	5.5
Chicago	48	25	7	0	....
Cincinnati	55	25	8	1.0	....
Denver	50	22	13	0	5.5
Pacific Coast States:					
Spokane	48	22	10	4.0	....
Portland, Oreg	53	16	8	3.0	3.2
San Francisco	56	5	6	0	....
Los Angeles	62	9	11	1.5	....
Arid West States:					
Boise	51	23	11	4.7	....
Santa Fe	49	22.5	11	1.5	3.5
Salt Lake City	51.6	22.2	10	2.5	4.0

[7] February 15 would be $\cos\left(180+\frac{\text{February 15–January 10}}{\text{July 30–January 10}}\times 180\right)=180+32°\ 24'=-\cos 32°\ 24'$, rather than $\cos\frac{360}{365}$ (February 15–July 30) $=\frac{360}{365}\times 200=\cos 197°=-\cos 17°$.

Table 1 contains the constants for equation (5) for 24 rather widely distributed representative cities of the United States. For all places except the arid West the last constant (see column 4) is 1 or less, and when multiplied by 2 cosines it becomes negligible; hence, the equation is still further simplified, becoming

$$T=Ma+\frac{Va}{2}\cos t+\frac{My}{2}\cos\theta \qquad (8)$$

The U. S. Weather Bureau has hundreds of cooperative weather stations where thermograph records are not kept. The data taken at these stations are sufficient to determine the constants of equation (5), and thus this equation can be used for determining hourly normal temperatures for these places.

About one-fourth of the earth's surface has a relative humidity of about 50 per cent; 80 per cent of the days are free from rain; the precipitation is from 10 to 20 inches; the sky clear most of the time; and hence the departures from the normals are comparatively small as the records show. Equations (5) or (8), therefore, will give *actual* temperatures with fair accuracy for dry areas. Further accuracy may be obtained with the aid of the weather forecast.[8]

In using this equation for the determination of minimum temperatures at smudging time it should be remembered that even though a frost usually occurs on a clear night when the thermograph record is likely to be uniform yet the frosts that do damage to crops are usually abnormal, following cyclones, while the equation gives normal temperatures. These normals from the equation considered with the observed departures from the normals during the preceding 24 hours should give a fairly accurate prediction of the minimum to be expected.[9]

[8] The average daily variability of temperature for the year for the United States is 4.4° F. and for the arid west 4.7° F. (Bulletin Q, p. 33.) In the United States the maximum temperature occurs one-seventh of the time at an irregular time because of cyclones and the minimum one-fifth of the time at irregular times for the same reason. (Bulletin Q, p. 19.) These facts give a slight indication of the departures of actual temperatures from the normal.

[9] The equation gives the most accurate results in the spring and fall when the damaging frosts occur because the time of sunrise at these seasons is about the mean for the year, and this mean is used in the equation.

HAILSTORMS IN NEBRASKA.

By Harry G. Carter, Meteorologist.

[Weather Bureau Office, Lincoln, Nebr., Aug. 12, 1920.]

SYNOPSIS.

From a study of all available hailstorm records from one hundred and fifty cooperative Weather Bureau stations and the regular Weather Bureau stations in Nebraska it was found that the average number of hailstorms during the season April to September, inclusive, was 3.2. Hailstorms are most frequent in May and least frequent in September. The greatest number of hailstorms occur about a month later than the time of greatest rate of temperature increase in spring.

The greatest number of thunderstorms is in June and the fewest in April. Although hail does not occur without a thunderstorm, but 7.2 per cent of all thunderstorms is accompanied by hail. The percentage is largest in April and least in August.

Reports of hailstones as large as hens' eggs, or even larger, are frequent, and although storms of such intensity are local, they cause considerable damage.

In compiling the data for the following discussion the season includes only the six months April to September, inclusive, as this is the active growing season. The period October to March, inclusive, has been ignored, as there is but little or no vegetation to be damaged during this period, and consequently the number of hailstorms has but little effect upon agricultural interests.

No effort has been made to differentiate between storms of different intensity. The fact that a hailstorm has occurred does not necessarily mean that crops have been damaged in its path. The fall of hail may have been light and the hailstones small.

A careful study has been made of all available hail records from one hundred and fifty cooperative Weather Bureau stations scattered throughout Nebraska, together with the records kept at the regular Weather Bureau stations. In keeping the early records the value of complete hail data was not appreciated by many of the cooperative observers, and hailstorms were not recorded as carefully and as completely at the cooperative stations as has now been found desirable. For this reason it was found necessary to confine this discussion somewhat to the data recorded at the regular Weather Bureau stations. Data from numerous cooperative stations, however, were used in making the deductions, and it is gratifying to note the marked agreement between the records kept at the regular Weather Bureau stations and the records from such of the cooperative stations as had complete records.

Sioux City, Iowa, across the Missouri River from Nebraska, has been considered as representative of northeastern Nebraska. The data from the Nebraska stations have been supplemented by data obtained from the records kept at the Weather Bureau station at Cheyenne, Wyoming. The data for Cheyenne have not, however, been considered in determining mean values.

The data in the tables cover the nineteen years 1901 to 1919, inclusive.

Average number of hailstorms each month.

Stations.	April.	May.	June.	July.	August.	September.	Seasonal.
Sioux City, Iowa	0.5	1.0	0.6	0.2	0.1	0.3	2.7
Omaha	0.8	1.1	0.5	0.2	0.1	0.4	3.1
Lincoln	0.8	0.7	0.5	0.4	0.4	0.3	3.1
York	0.8	1.1	0.6	0.2	0.2	0.2	3.1
Marquette	0.4	0.5	0.7	0.5	0.4	0.2	2.7
Genoa	0.4	0.8	0.5	0.4	0.2	0.1	2.5
Oakdale	0.4	0.9	1.2	0.4	0.3	0.4	3.6
Valentine	0.3	0.8	0.6	0.5	0.5	0.0	2.7
North Platte	0.4	0.8	0.5	0.6	0.5	0.1	2.9
Imperial	0.5	1.5	0.5	0.7	0.5	0.1	3.8
Kimball	0.1	0.7	1.9	0.9	0.8	0.2	4.6
Cheyenne, Wyo	0.5	1.5	2.6	1.3	1.2	0.9	8.0
Means	0.5	0.9	0.7	0.5	0.4	0.2	3.2

The above table gives the average number of hailstorms for each month, April to September, inclusive, and the total for the season, at selected stations throughout the State. It will be noticed that the greatest number of hailstorms is recorded during the spring months. For the State as a whole the maximum frequency is in May, with a gradual decrease until September, when the minimum occurs. Hailstorms occur with about the same frequency in April and July, which is a little more than half that for May.

In the eastern portion of the State the time of greatest frequency is May, becoming somewhat later as we go westward, and in the western portion more hailstorms occur in June than in any other month.

The fewest hailstorms occur generally in late summer and early autumn. Along the Missouri River the fewest storms are in August, becoming later to the westward, and in the central portion of the State the minimum number of storms is in September. In the western portion, however, fewer storms occur in April than in September. Note that during the 19 years a hailstorm has never been recorded at Valentine in September.

The total number of hailstorms for the season, taking the State as a whole, is 3.2. North of the Platte River the average is generally less than 3 storms each season, although there seems to be a small area, with Antelope County as the center, where there is an increase in frequency to an average of 3.6 hailstorms each season. South of the Platte River more than 3 storms are recorded each season. The number increases from 3.1 at the Missouri River on the east to about 3.8 in the southwestern corner of the State. There is also a rapid increase from 2.9 at North Platte to nearly 6.0 at the extreme western border of the State.

The accompanying table gives the change in mean temperature from the preceding month and shows the rapid increase in temperature during the period when hailstorms are most numerous.

Changes in monthly mean temperature.

Section of State.	March to April.	April to May.	May to June.	June to July.	July to August.	August to September.
Northeast	+12.2	+10.9	+ 9.3	+5.9	−2.2	−8.8
Southeast	+11.3	+10.5	+ 9.4	+6.0	−1.9	−8.6
Central	+11.3	+10.4	+ 9.7	+5.9	−1.9	−8.8
Southwest	+10.9	+ 9.8	+ 9.9	+6.0	−1.7	−8.8
West	+ 9.9	+ 9.2	+10.0	+6.2	−1.3	−9.3
Northwest	+11.1	+ 9.2	+10.5	+6.3	−1.8	−9.2
Means	+11.1	+10.0	+ 9.8	+6.0	−1.8	−8.9

For example, in the northeastern section of the State, April averages 12.2 degrees warmer than March; May, 10.9 degrees warmer than April; June, 9.3 degrees warmer than May; July, 5.9 degrees warmer than June; August, 2.2 degrees cooler than July; and September, 8.8 degrees cooler than August.

It will be noticed that the greatest increase in temperature is in April, while the greatest number of hailstorms is generally about a month later, or in May and June. This is what might be expected. The air near the earth's surface is warming rapidly in April, so that by the middle of May there is a large difference between the temperature of the air at the earth's surface and the air at a height of several miles. This is favorable for

strong convectional action, and as the formation of hail is dependent upon strong upward air currents, this period would be unusually favorable for the formation of hail.

From April there is a gradual decrease in the temperature increase for the State as a whole, and by August the change is a decrease in temperature. By referring to the table of hailstorms for each month it will be seen that there is a gradual decrease in the number of storms from May to August and September.

As hailstorms are an accompaniment of thunderstorms it is interesting to observe how many thunderstorms occur during the season.

Average number of thunderstorms each month.

Stations.	April.	May.	June.	July.	August.	September.	Seasonal.
Sioux City, Iowa	2.9	6.8	9.5	8.5	8.2	4.9	40.8
Omaha	3.6	7.6	9.7	8.6	8.5	5.7	43.7
Lincoln	3.8	7.2	10.1	9.9	9.2	6.3	46.5
York	3.7	8.6	11.3	10.8	11.5	6.0	51.9
Marquette	2.9	5.6	8.5	8.3	8.6	4.5	38.4
Oakdale	2.8	5.9	7.3	8.1	7.6	4.7	36.4
Valentine	1.4	4.9	9.4	8.4	8.6	3.8	36.5
North Platte	2.3	6.4	9.6	9.7	9.0	3.1	40.1
Cheyenne, Wyo	2.0	6.7	11.0	13.4	12.6	4.9	50.6
Means	2.7	6.6	9.4	9.0	8.9	4.9	41.8

For the State as a whole there is a gradual increase in the number of thunderstorms from April to June, and a decrease from June to September. June, July, and August, respectively, are the months of greatest frequency. There is a rapid decrease during September, and this month has a little more than half as many as August. The increase from April to May is rapid, more than twice as many thunderstorms occurring in May as in April.

In the eastern and northern portions of the State the month of greatest frequency is June. No set rule seems to apply to the remainder of the State. The period of maximum number of storms, however, is in one of the three months, June, July, or August, and seems to be a little later in the season in the central portion of the State than in the western. April is uniformly the month of fewest storms.

The total number of thunderstorms for the season, April to September, inclusive, varies from an average of 38 in the northern portion of the State to an average of 47 in the southern. In the northern portion there is a slight increase from 41 at the Missouri River to the westward, while in the southern portion there is an increase from 44 at the river to about 50 in the center of the State. Continuing westward there is a decrease to about 40, followed by an increase to about 50 at the western border of the State. The average number of storms for the State as a whole is about 42 each season.

As these tables indicate, all thunderstorms are not accompanied by hail. Some authorities state that from one-half to one-tenth of all thunderstorms are accompanied by hail. While this may be the case in some parts of the country, it does not hold true for Nebraska.

Percentage of thunderstorms accompanied by hail.

Stations.	April.	May.	June.	July.	August.	September.	Seasonal.
Sioux City, Iowa	16.1	14.6	6.1	2.5	3.7	5.4	6.6
Omaha	23.5	14.6	4.9	2.5	1.2	6.4	7.1
Lincoln	19.2	10.3	5.2	3.2	4.0	5.0	6.5
York	23.8	13.7	5.7	2.2	2.6	3.9	6.7
Marquette	13.5	8.8	8.5	6.7	4.5	3.7	7.1
Oakdale	14.8	15.9	15.8	5.2	4.2	7.9	10.0
Valentine	22.2	15.2	6.2	6.2	6.1	0.0	7.0
North Platte	15.9	12.4	4.9	6.0	5.8	1.7	6.9
Cheyenne, Wyo	26.3	21.9	23.1	9.8	9.6	18.1	15.7
Means	18.6	13.2	7.2	4.3	4.0	4.2	7.2

The above table gives the percentages of thunderstorms in Nebraska accompanied by hail in the different portions of the State. For the whole State, the greatest percentage is in April, when 18.6 per cent of all thunderstorms is accompanied by hail. As the season advances and thunderstorms become more frequent, the percentage is less, with a general decrease to August, when there is but 4 per cent. September has 4.2 per cent, or 0.2 per cent more than August.

Considering the State as a whole, 7.2 per cent of all thunderstorms is accompanied by hail. The lowest percentage seems to be in the southeastern portion of the State and the greatest in the western portion, with a secondary maximum in the central counties.

The general movement of hailstorms is from a westerly to an easterly direction. The path over which hail falls is usually of limited area. It is, in fact, quite common for the crops over but a small area to be damaged. This must not be misconstrued to mean, however, that this particular small area suffers loss year after year.

Hailstones of unusual size have been reported from various sections of the State. Authentic reports of hailstones as large as hens' eggs are not unusual, while occasionally hailstones even larger are reported. During a hailstorm at Stanton on April 25, 1893, the observer reported "hailstones 2 to 3 inches in diameter." At Madison a hailstone "3½ inches long" was reported by the cooperative observer during a storm on May 11, 1896. A hailstone "7¼ inches in circumference" was reported at Hebron April 18, 1893, and one "7½ inches in circumference" at Nebraska City on September 5, 1898. The observer at Hayes Center entered on the official record for August 11, 1910, "Terrific hailstorm; hailstones 9 inches in circumference," and on May 31, 1900, noted "hailstones 2½ inches in diameter."

Hailstones of this size kill small animals and birds, literally pound the crops into the ground, strip small branches from trees, break windows, and even damage the walls and roofs of frame buildings. Great destruction is sometimes left in the path of such a storm. Fortunately, however, storms of this intensity are the exception rather than the rule in Nebraska.

LARGE HAILSTONES AT KANSAS CITY, MO., MAY 14, 1898.

At 7:25 p. m. hail began (the dividing line was about 75° zenith distance), the stones being of enormous size, rendering insignificant all previous records of hail at this station. The hail ended at 7:37 * * * . The official in charge measured between 15 and 20 of the largest hailstones and found them to range from 8 to 9½ inches in circumference. They were unusually well-formed and very solid. Quite a number were almost spherical; the majority were egg-shaped with one side rather flat. Very few had irregular surfaces or protuberances. The larger ones, when cut, showed 7 and 8 concentric layers outside the core. They were frozen hard, and a number of the heavier stones sank their depth in lawns and vacant ground.

The width of the hail belt was about 4 miles, but the very large hail was confined to this city, the area being little less than 3 square miles.

The damage by hail was very great. South windows and skylights were broken in nearly every house in the central and eastern portions of the city. Greenhouses suffered almost complete destruction. Horses, pelted by the hail, ran in every direction. Several persons were injured in one way or another. The roofs of buggies and carriages afforded no protection against such bombardment. Slates were broken on roofs. Fruit trees in the

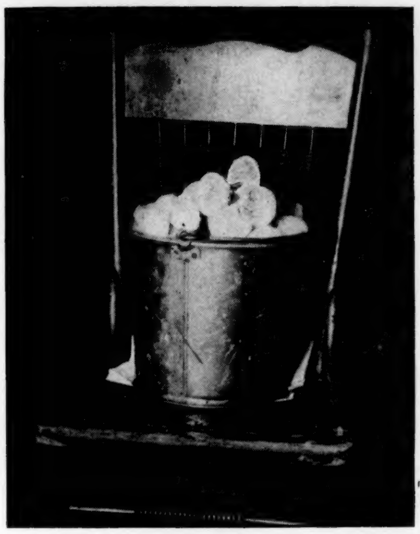


FIG. 1.—Hailstones "Taken over an hour after storm." (The farmer "made ice cream at night—had to break all pieces to go in freezer.")

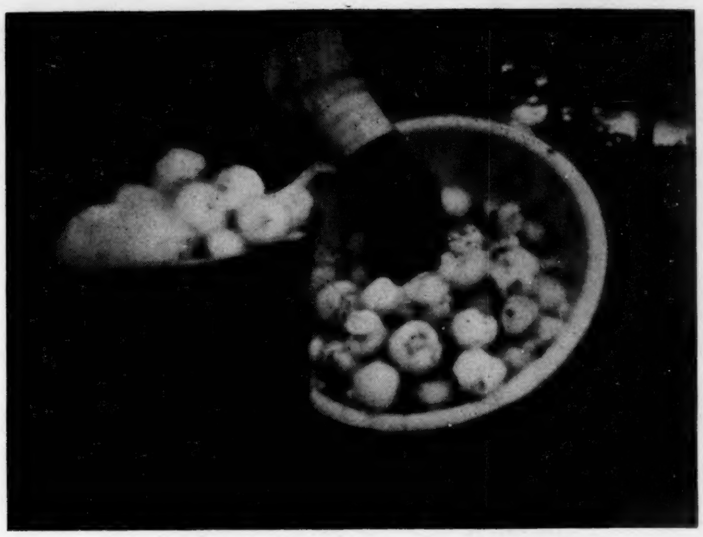


FIG. 2.—Hailstones picked up after a severe hailstorm.

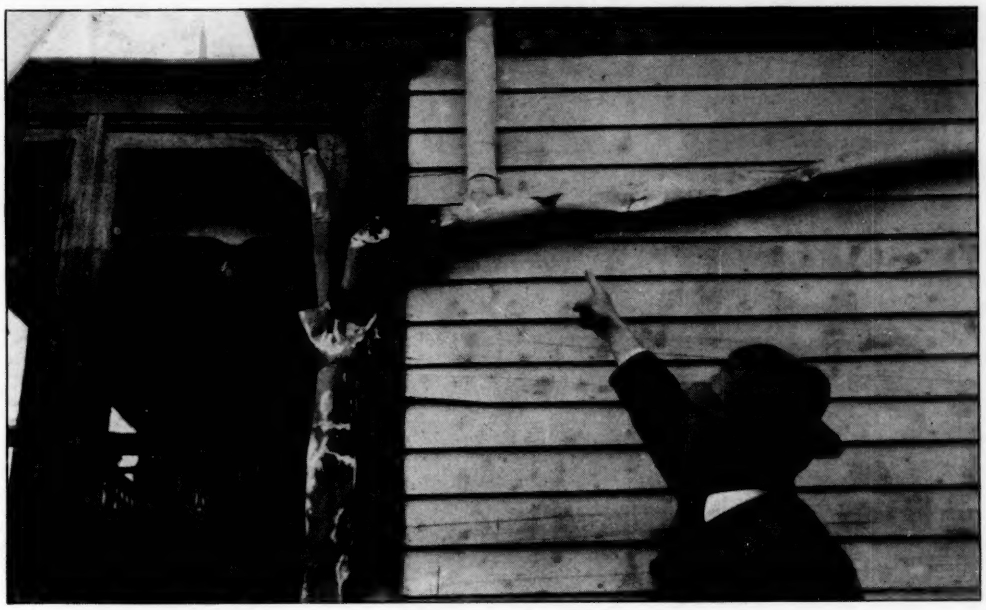


FIG. 3.—An eave spout damaged by hail. Note the dents in the siding.

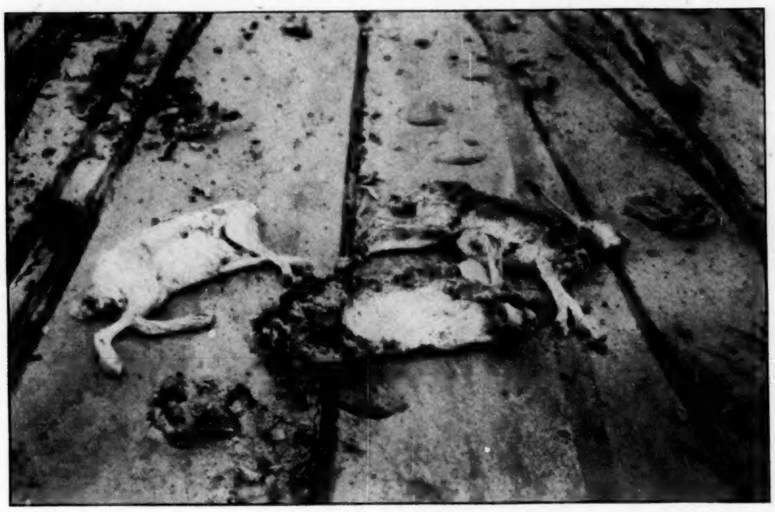


FIG. 4.—Rabbits killed by hailstones August 8, 1917, in York County. The three rabbits were found within a distance of half a mile.

FIG. 5.—Farm house in York County damaged by hail, August 8, 1917. The owner can testify as to the severity of the storm.

eastern half of the city were stripped of fruit buds and foliage, and plants, flowers and vegetables were crushed to the ground.

Prof. James A. Merrill, of the Manual Training High School of this city, informed the writer that he found one hailstone showing 11 concentric layers.

The accompanying picture is a copy of a photo made by a Kansas City man of hailstones that fell in the great storm of May 14, 1898. I had a negative made from the old photo, from which this print was made. The hailstones were placed on a brown cloth, the ground being covered with hail, together with two large hen eggs, each showing a small cross in order to show by contrast the size of the hailstones.

[A half-dozen of the principal losses alone totaled over $17,000.]—*P. Connor.*

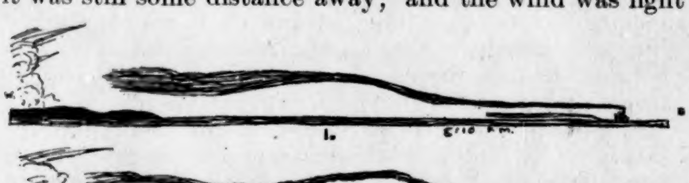
FUNNEL CLOUD OVER LAKE MICHIGAN, JUNE 29, 1920.

The cloud in the accompanying sketch was seen over Lake Michigan, on looking north from Chicago, at 7:08 p. m. (local summer time), June 29, 1920. The point of the cloud was actually considerably lower than the bulging top, and the drawing shows it as well as I

could represent it. No rotary motion was noticed in connection with the cloud. It changed shape rapidly, and by 7:13 had disappeared. A thundershower of moderate intensity followed within five minutes.—*Allen H. Ward.* This cloud probably marked a vortex which with but little further development would have made a waterspout.—*C. F. B.*

A SMOKE ARCH MARKING AN INCREASE IN WIND.

The sketch, which was made looking north from Chicago on the evening of August 6, 1920, shows a curious curve in a streak of smoke from a small steamer. A thunderstorm was approaching from the west, though it was still some distance away; and the wind was light



(Local Summer Time)

to gentle east to southeast. The curve was first noticed at 8:10 p.m., but became most pronounced three minutes later, with little change in position. By 8:18 it had moved westward considerably. It then began to fade away, and was last seen at 8:25, being then partly over land. At Chicago, the east wind shifted to southeast and increased from light to moderate about 15 minutes after the smoke had disappeared.—*Allen H. Ward.*

SOME FLYING EXPERIENCES IN "BUMPY" WEATHER IN TEXAS.

By D. P. CARLBERK.

[Excerpts from a letter to the Editor, Jan. 20, 1820.]

Entering Barron Field, Everman, Tex., as a cadet I flew there till I was commissioned and thereafter till I was ordered to Post Field in September. Having been both a cadet and an officer through a Texas summer I feel that I am quite familiar with most of the conditions treated in your article.[1]

The "bump" that worried me most was that kind I always thought of as a slender shaft of upcurrent. The big ones lift the whole ship but those wicked little ones kick one wing so sharply and so suddenly, I wondered whether I would ever get to the point where they would not scare me.

After a pilot gets to the place where he is accustomed to the roar of the motor, and the whistling of the wind through the wires, he can hear new sounds, and the contact of those upshoots—the "slender" ones—with the wing surface can actually be heard. It sounds as if someone under your wing had taken a hand full of sand and thrown it up against the wing—kind of a "biff" with a soft hiss to it.

One very hot day I was on a long cross-country flight. Fifteen miles south of Midlothian, Tex., I ran into a mess of "bumps" that were far worse than usual. I sat up and gave attention to the stick when suddenly a big fellow took me in charge—lifted me up about 500 feet and, regardless of my efforts and the power of the "Hispy," swiftly turned the whole ship completely around so that I started back toward the town. The twist seemed to come at the top of the current. I experienced the same twist on two different occasions after that. I could never understand it, unless it so happened by there being two large upcurrents side by side and as their overflows met at the top the twist was created, and that I was caught or tossed to one side, as I reached the top, and there met the twist (between the two "bumps").[2]

The height of "bumpiness" on any particular day does not remain constant. One day I flew for an hour at 5,000 feet. There was not a suggestion of a "bump" above 3,000 feet. When I landed, a pilot, ready to go up, asked me about the air. I had just landed so told him there was perfect air anywhere above 3,000 feet. I happened to be on the line when he came down and he told me that he had gone at once to 5,000 feet and the whole area was covered with "bumps."

Here is a peculiar thing which you doubtless will understand at once but was ever strange to me. It happened a half dozen times at Barron Field.

We always like to fly best in the early morning hours for the air was always good, but if that high, hot, wind—

[1] "Effect of winds and other conditions on the flight of airplanes, MONTHLY WEATHER REVIEW, August, 1919, 47: 523-532.

[2] Upcurrents are frequently strongly rotational (especially in dust whirls), so only one convectional column would be sufficient to cause Mr. Carlberk's experience.—*C. F. B.*

for which Texas is famous—blew steadily all night, the early flying hours were just as rough as those at noonday. When I first found the rough flying so early in the morning I was much concerned and sought everywhere for a reason. I think an officer told me it was due to the wind blowing all night. I watched it thereafter and found it to be a fact.

I feel that none of the boys have exaggerated when they told you of the great drops and lifts they have gotten from "bumps." While my greatest lift or fall would not exceed 1,500 feet I know of much greater.

DISCUSSION.

The bumpiness of a wind that has blown all night seems to be owing to the turbulence induced in the wind as it goes over the uneven ground. In much of Texas the unevennesses of scattered woods and occasional valleys would be enough to produce the effect observed. The turbulence created in this way gradually reaches to greater and greater heights: thus the wind that has blown all night may be turbulent through a layer of perhaps 1,000 to 3,000 feet.—*C. F. Brooks.*

AERIAL CONDITIONS IN AFRICA.

Some notes on the use of the aeroplane in African exploration by Lieut. L. Walmsley in the *Geographical Journal* for November (vol. liv., No. 5) are valuable in giving the results of experience. Mr. Walmsley points out that "air pockets" are normally encountered during the daytime in tropical Africa up to a height of about 6,000 feet. As a result he had to do his aerial photography in East Africa in the morning and evening, when the light was not favorable. Above 7,000 feet, however, he thinks that operations could be carried out all day long.—*Nature (London), Dec. 11, 1919, p. 379.*

An Airman's Experience in East Africa.—There is much of interest to meteorologists in the articles by Leo Walmsley entitled, "An Airman's Experiences in East Africa," which have appeared in ***Blackwood's Magazine*** (November and December, 1919).

The author, who served as an aeroplane observer during the war, gives a vivid account of his experiences. The dangers due to the "bumpiness" of the air were frequently serious. In the "most terrific bump of all" "the machine dropped like a stone 200 feet at least, and at such a rate that my field glasses were whipped off my shoulder and were caught in the rigging, two or three yards behind. The pilot's glasses held by the strap on his flying cap, and for two seconds they were suspended in the air above his head." Other adventures included flying through clouds almost into the flank of a mountain and reconnaissance carried out whilst surrounded by thunderstorms on all sides.—*Meteorological Office Circ. 43, Jan. 6, 1920, p. 2.*

Over Egypt and the Sudan.[1]—The desert is the playground of the winds. The wind builds up hills and lays them flat. It blows now hither, now thither. Here it lifts up the sand in great clouds that darken the sun. There it pours down the blessed rain. And the sand drinks up the rain, and laughs. That is how we found the desert in our first two days' flight. * * *

Heavy rain and a bad wind kept us at Heliopolis until 9:18 a. m., February 23. We then got away, intending to make Assuan in the day. Soon after starting we had trouble with the port-engine petrol pump. * * *

[1] From an article on "Cairo—Cape Flights: Why they failed," by Maj. C. C. Turner.

We saw little blue sky; and soon the sun was almost completely obscured by mist. About noon a sandstorm was seen away on our port bow, and very menacing it looked. Indeed, neither the desert nor the sky had a smile for us that day. The sandstorm whipped the surface of the desert almost white, the foam of this waterless ocean, and it swept on, an ugly gray-brown cloud that must be hell for anyone in it. Sandstorms are things to be avoided by aeroplanes; they would strip struts and wings and propellers. Rain is bad enough, as we were soon to know. It frayed the cutting edges of our propellers, making many bad patches which had to be repaired and repainted at the first landing.

The rain got worse, and made visibility poor. We were looking for Assiut, and at the very time we were nearly due we were over a place that tallied with it by our map. We landed at 1:15 on the sand close to the houses, and immediately a picturesque crowd of men and boys came running toward us. * * *

On the following morning it was raining, after a curiously warm night. We had slept the sleep of tired dogs in our sleeping bags on the sand of our host's tent. Owing to the delays caused by the weather and the distance of supplies we did not get away from Assiut till 10:45, which meant flying through the hottest hours of the day, and we were very soon to know what the sun can do. The wind, however, was in our favor to the extent of about 18 miles per hour, and we had strong hopes of making Wady Halfa in one flight. We got away in grand style. * * *

The sky rapidly cleared, and before long there was scarcely a cloud to be seen. But that was after a bad patch of rough work for the pilot when the machine, under lumps of heavy clouds, seemed reluctant to keep altitude. There was a time when it looked as if we were in for a return of the previous day's trouble.

Flying at a height of 5,000 and 6,000 feet under these skies, and with 10,000 square miles of desert spread out below, was extraordinarily impressive. But even under a pure blue sky the desert looks terrible. At one part of that day's flight nothing was visible but the desert, although to the expert eye a faint thin line hugging the horizon on one side might have revealed the valley of the river. * * *.—*Aeronautics (London), Mar. 25, 1920, p. 253.*

SOUTHERLY WINDS AT HIGH ALTITUDES OVER LANSING, MICH., DURING SLEET STORMS OF JANUARY, 1920.

By C. G. ANDRUS.

[Weather Bureau, Lansing, Mich., July 9, 1920.]

In studying Mr. C. LeRoy Meisinger's paper on "The Precipitation of Sleet and the Formation of Glaze in the Eastern United States, January 20 to 25, 1920," which appeared in the February number of the MONTHLY WEATHER REVIEW, 1920, pages 73–80, I found in our local pilot-balloon records two items which Mr. Meisinger did not possess at the time of writing the paper.

The first of these is pertinent to his discussion (p. 76, column 2) of the wind boundary and cloud forming levels above this meridian, and is in the form of a note on the pilot-balloon ascension report at 7 a. m., January 21, 1920. This note refers to the 5/10 alto-stratus cloud covering observed at that time and reads: "White striations of alto-stratus filaments north to south, but moving rapidly from west." This seems to me to be a clear indication that the clouds formed from vapor thrust into the westerly current by another current from the south. I think this was one of the occasions when this cross-hatched effect was very noticeable.

The other item is the finding of the balloon identifying tag, attached to the balloon released here at 3 p. m., January 21, 1920. It was found late in April, 185 kilometers from Lansing, along azimuth 80° (East 10° north), at a point 5 miles northeast of Port Lambton, Ontario. This balloon was observed up to an altitude of 6 kilometers, during which altitude a westerly gale without southerly component was found. From the time it was lost to view at 31 kilometers distance until it landed at Port Lambton it pursued a course averaging 78 degrees, part of which contains the north component which existed over this part of the country in the lowest 2-kilometer layers of the atmosphere. Therefore, the wind, during a large part of the voyage to Port Lambton, must have been from a nearly southwest direction at a high rate of speed, indicating a large southerly component of velocity.

While there is nothing definite at hand concerning the altitude where the southerly component prevailed, it is of interest to know that it existed somewhere above the 6-kilometer level of the air.

Both of these items are in accord with the conclusions which were arrived at in the discussions of sleet and glaze.

THE STRUCTURE OF THE ATMOSPHERE WHEN RAIN IS FALLING.

By V. BJERKNES.

[Abstracted from Quart. Jour. Roy. Meteorological Soc., April, 1920, No. 194, **46**: 119-138, disc. 138-140, 17 figs.]

In this lecture before the Royal Meteorological Society Prof. Bjerknes presented later developments of study by H. Solberg and J. B. Bjerknes under his direction, arising from the Scandinavian weather begun in the interests of daily detailed local forecasting in Norway, in the summer of 1918. Earlier Bjerknes papers (this REVIEW, Feb., 1919, **47**:90–99) made clear the nature of wind circulation in cyclones and the cause of the distribution of rainfall as it was. Cold air already in the region, when attacked on the flank by relatively warm air is overridden by the latter and a moving rain-stripe 150–300 km. wide is formed by the consequent precipitation. Associated with this rain-stripe and at another angle to it is a narrow stripe of intense rainfall marking the line where cold air underthrusts the western flank of the warm current. (See fig. 1.) The former is called the steering-line and the latter is the well-known squall-line. In this new paper the conditions in some specific cases are carefully described and the magnitude of the operation estimated. The rainfall ordinarily occurring in the belt immediately east or north of the steering-line is said to represent 1,000 million H. P., or the equivalent of a waterfall equal to fifteen Niagaras.

The concluding paragraph of his discussion of the moving cyclone is worth quoting:

> The appearance of the sky in the different parts of a cyclone, at different distances from its center and in different situations relative to the steering and squall-lines, is so characteristic, and develops in so typical a way during the passage of the whole system, that it will always be recognized when one has once become acquainted with it. Of course the formation of clouds and rain of local topographical origin may change the picture, but not in general beyond recognition, and these local changes of the picture should be studied carefully at every place. When this is done, observation of the phenomena of the sky will be seen to have an importance equal to the study of the weather chart, especially for short-range forecasts. The time should be past when weather forecasts are made as bureau work in an office from which only a narrow strip of the sky is seen.

A distinctly new contribution to local forecasting is brought out in his description and explanation of the distribution of local thunderstorms in Norway in a selected 6-day period in summer. The showers developed by day only where solar winds (i. e. sea breezes and valley winds) converged, but not all such points of convergence had showers on the first, second, or even third day. It was found that not till moist air arrived from the sea was it possible for showers to develop over inland convergence points. The divergence points were, of course, over glaciers, fiords, and large lakes, and hence these and their surroundings remained dry on account of descending air.

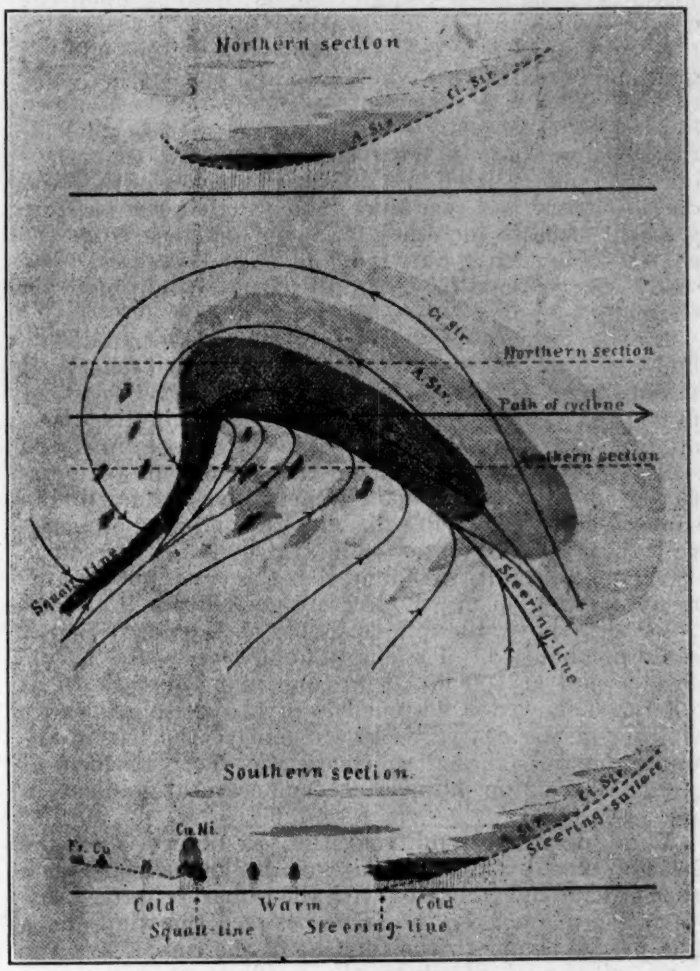


FIG. 1.—Distribution of cloudiness and precipitation in a moving cyclone.

After the third day, however, nocturnal rains began to occur over such valley areas, for the cold mountain breezes at night smoothly underran and lifted the relatively warm, moist air over thse bodies of water and their shores.

Rains in cyclones and such local showers are due to new air and to overrunning, up-thrust, or local heat convection.

For greatest success the forecaster should find the region of convection, using stream-line charts, and by observation of humidity and other factors follow the advancing front of new air. With such information, detailed forecasts are now being made as to when and where precipitation will occur, and the method seems to hold the possibility of foretelling how much will fall as well.—*C. F. B.*

INVESTIGATIONS OF THE CHANGE OF WIND WITH ALTITUDE IN CYCLONES.

By MARIE DIETSCH.

[Abstracted from *Veröffentlichungen des Geophysikalischen Instituts der Universität Leipzig*, Band II, Heft. 5, 1918. Original translated by W. W. Reed, U. S. Weather Bureau, Atlanta, Ga.]

In this work the author discusses cyclones with reference to the relations between wind direction and velocity at various levels to the pressure distribution prevailing at those same levels. The cyclones are divided into quadrants designated "front," "right," "rear" and "left," consideration being given, in deciding upon the quadrant in which an observation should be placed, to the direction of progression of the cyclone itself; and the quadrants are further divided into an inner and an outer region. Thus are taken into account the well-known facts (1) that pressure systems change with height; (2) that cyclones are moving formations and that their inertia manifests itself in a different behavior of the wind on their front and rear sides; and (3) that the pressure gradient usually increases for some distance from the centers of cyclones outward and then decreases. The study was confined for the most part to conditions over Germany.

In the absence of sufficiently well distributed kite flights it was necessary to construct isobaric charts at various heights by an extrapolation of the sea-level pressures. This was accomplished by computing free-air pressures from the observed sea-level pressures and surface temperatures; in doing this a constant temperature gradient of 0.5° C per 100 meters was assumed. In some cases it was possible to compare computed pressures with those actually observed in kite flights; as a result of such comparison it was found that there was good agreement up to 1000 m.; moderately good up to 1500 and 2000 m.; above these levels the extrapolated values could not be used. The charts finally used—103 at the surface and at 500 m., decreasing in number to 79 at 2000 m.—showed a flattened form of the isobars and a shifting of the center backward and to the left in the upper levels. These tendencies are most decided of course when the horizontal temperature gradient is steepest.

Wind directions and velocities, as observed on the selected days by means of kites and pilot balloons, were then studied in connection with the isobaric charts. The deviation angle, i. e., the angle between the wind and a line perpendicular to the tangent of the isobar, and the ratio of the observed to the gradient velocity were measured. The results, when all cases are considered and when a few typical cases are selected, are set forth separately, but the differences are not large. In general the deviation angle increases rapidly from the surface to 500 m., then more slowly up to 2000 m., where it is nearly 90°, i. e., the wind is practically at right angles to the pressure gradient. The component toward the center of the cyclone is greater in front than in the rear, due of course, to the forward movement of the cyclone. There appears to be no consistent difference in the deviation angle in the inner and outer regions of cyclones. The ratio of observed to gradient velocity increases rapidly from the surface to 500 m., but above that level remains relatively constant—in most cases somewhat less than 1; in other words, the gradient velocity is not quite reached, on the average. There is little difference in this ratio in the different quadrants, but it appears to be somewhat larger in the outer than in the inner region of cyclones.

It is pointed out that the difference in the deviation angles in the front and rear of cyclones has a very direct connection with the movement of those cyclones. The convergence in front tends to increase cyclonic circulation; the divergence in the rear tends to decrease it. Since the movement will be toward the region of strongest convergence, observations of the latter in individual cases should help materially in determining probable storm movement.

DISCUSSION.

Meteorologists have long recognized the necessity of having accurate representations of free-air pressure distribution before much further progress can be made in forecasting. Particularly urgent is the need for these, now that specialization in forecasting for aviators is receiving so much attention. The author of the work above reviewed has made a careful and well-planned study of the subject, and in general the method of treatment is entirely logical. The results are compared with those of other investigators, and the different conclusions reached are shown to be due to the fact that earlier students considered the free-air winds in relation to sea level pressure distribution instead of that at the level of the winds themselves. There is no question as to the nonconformity of free-air isobars to those at sea level, except occasionally when horizontal temperature gradients are very weak. (This condition seldom occurs in cyclones.) In a study of the dynamics of the free atmosphere the method employed by some investigators of considering free-air winds in connection with sea-level pressures is therefore quite erroneous. Misleading impressions are made on the mind of the reader, unless care is taken continually to keep before him the actual basis of comparison; on this basis no real progress is possible. From a practical point of view, however, this method of treatment has its advantages. It is frequently the case that free-air observations can not be made in certain regions and that lack of time does not permit the meteorologist to construct free-air isobaric charts. In such instances a tolerably accurate forecast can be made, based on the results of the studies just referred to. Of particular value are these relations to aviators, who naturally wish to know what the conditions are, not the reasons for them.

The author points out a possible weakness in her method of computing free-air pressures, viz., that of assuming everywhere a temperature gradient of 0.5° C. per 100 meters., but defends this method by citing the average values in cyclones as determined by Peppler.[1] This is true when the mean gradient up to 2000 m. for the year is considered. There are very appreciable variations, however, for the different levels and there are large *seasonal* differences. It is believed that the latter at least should have been considered. An idea of the importance of these may be gained from an examination of figures 5 to 10 in a paper recently published by Mr. Meisinger.[2] These figures and the accompanying text, bring out clearly the variations in the free-air temperature gradient with height, season and wind direction and indicate that these variations can not be ignored. What are needed more than all else, as the author remarks, are numerous *current* observations, so that the free-air pressure distribution may be *known*, not estimated. We all join in the hope that this condition may soon be realized.—*W. R. Gregg.*

[1] Die vertikalen Gradienten der Temperatur und die Schichtungen in den Cyklonen und Anticyklonen. Beitr. z. Phys. d. fr. Atm., Bd. IV, S. 67, 1912.

[2] Meisinger, C. LeRoy. Preliminary steps in the making of free-air pressure and wind charts. MO. WEATHER REV. May, 1920, pp. 251-263.

EXPOSED STEEL TEMPERATURES IN THE TROPICS.

By H. G. CORNTHWAITE, Assistant Chief Hydrographer.

[Section of Meteorology and Hydrography, Canal Zone.]

A series of observations was made at Balboa Heights, Canal Zone, during the month of April to determine the maximum heating of steel or iron exposed to the sun's rays in the Tropics.

Method of exposure.—Blocks of steel 2 by 2 by 12 inches were exposed to the sun's rays in a manner favorable for maximum heating. These blocks were placed across a 1 by 4 inch plank lying flat on a concrete pavement inside the instrument inclosure (fence). An 8 or 10 inch board was stood up edgewise a few inches from the blocks on the windward side to protect them from the wind movement, which was at all times very light immediately above the surface of the ground inside the fenced inclosure. The protection from wind movement obtained was not complete, but it was nearly so. It was thought to represent approximately the exposure found in the more protected sections of steel structures exposed to solar radiation.

The observations were made during the latter part of April with the midday sun directly overhead and its rays falling vertically on the earth's surface. A one-half inch hole was drilled into the center of each steel block. The resulting well was filled with mercury and readings were made at 15 minute or half hour intervals by immersing the thermometer bulb in the mercury well.

Records.—The highest steel temperature observed was 133 degrees F. at 3:30 p. m. April 26th. It is estimated that under the most favorable natural conditions possible in the Canal Zone the maximum temperature of exposed steel is not likely to exceed 140 degrees F.

Similar records of the temperature of exposed steel at stations in the United States or elsewhere are not at hand. It is thought, however, that the maximum temperature of exposed steel is higher in the Canal Zone than in the more humid sections of the United States, but lower than in the dry sections of the West and Southwest, as humidity in the atmosphere absorbs a considerable percentage of the sun's heat and diminishes the solar radiation reaching the earth's surface. It is estimated that the maximum exposed steel temperatures in the deserts of the Southwest may reach 160 degrees F. or higher. If not already available, it is suggested that it might be well to obtain a series of exposed steel temperature records at a few selected stations in different sections of the United States. These data would be of value to structural-steel engineers and designers who must figure the expansion and contraction of steel, covering the expected maximum range in temperature.

The following may be mentioned, illustrating the effects of temperature changes on steel structures of precise dimensions:

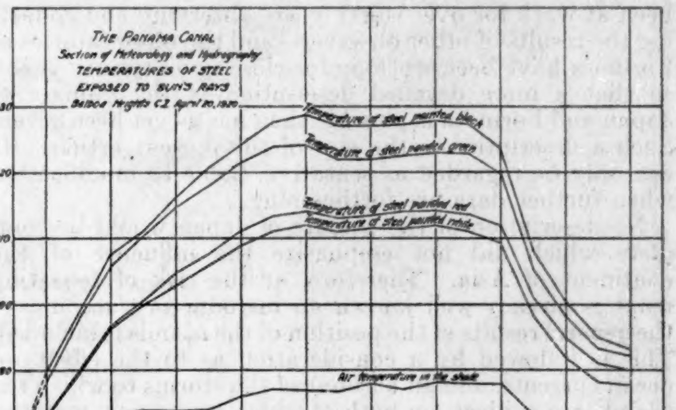
The steel spillway gates of the Panama Canal were designed to be as nearly water-tight as possible, and the leakage through them is very small. In measuring this leakage it was found to vary somewhat throughout the day, being regularly heavier during the daytime than at night, due to the action of the sun shining on one side of the gates and causing the metal on the exposed side to expand and the gates to buckle or warp slightly, thereby increasing the leakage.

Influence of colors on exposed temperatures.—Experimental observations were made to determine roughly the comparative heat absorbing properties of various colors exposed to the sun's rays. Blocks of steel of similar size and shape painted black, white, red, and green were exposed side by side.

Regarding the composition of the paint used it, was realized that it would be best to use paint of identical composition, except for the coloring pigment, but we had no equipment for mixing paints and were unable to do this. The paint used was obtained from the paint shop. I think its ingredients were linseed oil and ground white lead for the green, white, and red paint, plus the coloring pigments in the green and red paint. I am not sure regarding the black paint, but I think some other element was used instead of linseed oil, as it dried rapidly. The luster seemed very much the same in the various paints, which would seem important in the question of absorption.

The results obtained were not thought to be exact, but only approximate. It is probable that repeating the observations would not give precisely the same records, but very similar ones. Records made two years earlier with the same black and white blocks, but different coats of paint, were similar, but they showed a somewhat larger "spread" between the black and white steel temperatures, but the exposure was slightly different, both blocks lying flat on the concrete inside a skeleton or bottomless box.

Successive temperatures of each throughout the day are shown on the attached diagram (fig. 1).



Of the various colors black is known to absorb the maximum percentage of solar radiation and white absorbs the minimum per cent. It will be seen that colors have a very pronounced effect on the temperature of bodies exposed to direct solar radiation. A maximum "spread" of 20 degrees F. between the black and white steel temperatures was observed on one occasion. The red steel temperatures are only slightly higher than the white, indicating that red is not the warm color that it is popularly believed to be. On the other hand, green seems to absorb nearly as much heat as black.[1]

Experiments with cloth of different colors gave similar results, indicating that in hot weather one's comfort may be promoted by selecting wearing apparel of colors that have low heat-absorbing properties.

[1] Cf. experiments cited by Dorno, MONTHLY WEATHER REVIEW, June, 1920, 48: 351.

The results obtained in these observations are thought to be only roughly comparable, since varying atmospheric and other conditions may affect the readings, such as wind movement, humidity, intensity of solar radiation, composition of coloring matter, etc.

DIURNAL PRESSURE CHANGE IN GULF OF FONSECA.

Capt. E. S. Jackson, commanding officer of the U. S. S. *Tacoma*, recently reported through the Hydrographic Office what he considered to be an instance of unusual diurnal pressure change. During the period from January 29 to February 29, 1920, while the *Tacoma* was stationed at Amalpa, Honduras, Gulf of Fonseca, Capt. Jackson observed daily between the hours of 12 noon and 1 p. m. a very sharp fall in the barograph trace. The average drop for an 8-day period, from January 29 to February 4, inclusive, during which the fall was most pronounced, was slightly more than 0.05 inch. There was no accompanying noticeable weather change.

Central America is on the northern edge of the area of greatest diurnal pressure variation in the Western Hemisphere, an area which, roughly, embraces Central America and the north-central portions of South America. As an example of the change that may occur in this region it is noted that at Mexico City the average diurnal fall in pressure from noon to 1 p. m. is about 0.04 inch.

The hourly rate of fall is, however, considerably less than that observed by Capt. Jackson for the hour 12–1 p. m., although the average total fall for all the afternoon hours is fully as much.

The barometric trace from the Weather Bureau station at Swan Island, off the northern coast of Honduras, the nearest point from which such a record is available, shows no unusual characteristics for the period in question.

Capt. Jackson has promised a further report to be made from La Union, Salvador, also in the Gulf of Fonseca.

THE CLIMATE OF JAPAN AND FORMOSA.

By ELLEN MARY SANDERS.[1]

The climate of the festoon of islands which begins in the south with Formosa near latitude 21° N., and stretches northward to Yezo near latitude 46° N., is exceptionally interesting, not only as illustrating the change of climate which naturally comes about with such a change of latitude, but because it presents so great a contrast to the other countries bordering the oceans lying in the same latitude. A large body of data is now available, since the Central Meteorological Observatory of Tokio has been at work for over thirty years observing and collecting the results of other observers, and the observatories of Formosa have been working for close upon twenty years, so that a more detailed description of the climate of Japan and Formosa is possible than has as yet been given. Such a description is the aim of the present article. It can only be regarded as tentative, liable to modification when further data are forthcoming.

No description of the climate of Japan would be complete which did not emphasize the influence of the continent of Asia. Therefore, at the risk of repeating what is already well known an introductory account of the general results of the position of the islands is included. This is followed by a consideration as to the effects of ocean currents, and an account of the storms to which the islands are subject, on both of which topics new material is available. After these general considerations a detailed description of the climatic zones is given, based on the reports of the observatories of Japan and Formosa.

General results of position.[2]—Japan is situated off the east coast of Asia, so that during the cold season it has an immense stretch of frozen land to windward, and as a result its temperature is far colder than is normal for its latitude. In addition to the modification in temperature the distribution of rainfall is also a result of the proximity of the great land mass.

In winter the central part of Asia becomes an area of high pressure since the land cools more quickly than the water, therefore the winds blow out from the center. Fig. 1 shows the winter winds of Japan and Formosa. Japan comes into the track of those winds which blow from the NW. coming across the cold lands of northern Asia. To these winds the north coast of Japan owes its rain, and the cold winter, particularly marked in the island of Yezo. Formosa, on the other hand, comes into the zone of the NE. Trade Winds during its cool season, and thus has winds coming over the ocean from a northeasterly direction.

In summer the central part of Asia becomes an area of low pressure, due to the heating of the land mass, and consequently winds blow in toward the center from all sides. Fig. 2 shows the direction of such of these winds as cross Japan. It will be noticed that they blow from the SE. and that they traverse the ocean before reaching Japan, thus they are warm, moisture-laden winds. To these winds the southern coast of Japan owes the greater part of its rain, while Formosa, which lies far enough to the south to get the full force of the Monsoon, shares with China one of the heaviest rainfalls of the entire globe.

Ocean currents.—It was formerly thought that the ocean currents which flow in the adjoining seas were one of the most important factors of the climate of Japan. Recent investigations have led to a modification of this view. Therefore it is necessary to examine the effects of the ocean currents on the climate.

There are two warm ocean currents, the Tsushima and the Kuroshio, and one cold current, the Oyashio. The warm current, called the Tsushima, enters the sea of Japan through the strait of Korea and touches the northwest coast of Nippon.[3] The curve of the isotherms on the west coast of Japan, which may be seen in Fig. 7, is perhaps due in part to this current, although, in the main, the relief is responsible for the course of the isotherms. A large amount of the fog and rain which comes to the west coast during the winter may also be due in part to this current, since in winter the prevailing wind comes straight from the part of the ocean which is warmed by it.

The cold current, called the Oyashio, flowing in a southwesterly direction, touches the eastern and southern coasts of Hakodate and also eastern Nippon, and may contribute toward lowering the temperature of these districts. The other warm current, the Kuroshio, which touches the southern coast of Nippon in its course toward the northeast, is far more powerful than either of the others, and higher in temperature than the Tsushima. The great amount of rain on the southeastern coast of Japan during the summer may be partly due to this current.

[1] B. A. London and Bristol, England; Docteur de l'Univ. de Paris, France; British scholar, Bryn Mawr, U. S. A.

[2] Atlas of Meteorology. Bartholomew and Herbertson, (a) Plate 14 Pressure.

[3] Art. 4, Vol. XXXVII, Journal of Coll. of Sc. Imperial Univ. of Tokio.

In the report of the Central Meteorological Observatory of Japan, issued in 1893, it is stated that the effect of the Kuroshio is far less than that of the other two currents, and that the current view as to the great effect it has upon the climate is incorrect. This conclusion is supported by the fact that in winter the average temperature of Japan is 10° F. colder than is normal for its latitude. This is in striking contrast to the state of affairs in the British Isles, where the average winter temperature is 30° F. warmer than is normal for its latitude and shows that the influence of the warm currents on the climate of Japan is not comparable to that of the Gulf Stream upon climate of the British Isles. The same report as is quoted above also emphasizes the effect of the two smaller currents, but the isoanomalous lines, as given in the Meteorological Atlas, hardly support this view.[3] It seems as if more detailed research work on the subject is necessary before any satisfactory conclusion can be drawn.

Storms.—Not only is the climate of Japan profoundly modified by the influence of the continent on the west and the ocean on the east, but the storms which sweep across it play their part. Fig. 15 shows that Japan receives a large number of cyclonic storms every year. The shading on the map shows the frequency of these storms during the years 1905–1915. The map is based on the daily weather maps issued by the Central Observatory of Tokio, which are by far the most detailed and accurate data yet available. When comparing it with maps which show the frequency of cyclonic storms in Europe it must be borne in mind that the areas into which the Japanese map is divided are 2½ degrees of latitude by 2½ degrees of longitude, while the more usual system is to divide the map into areas of 2½ degrees of latitude by 5 degrees of longitude. Allowing for this fact, it is apparent that Japan has not as many storms as western Europe or as the eastern part of the United States,[4] but that enough storms strike Japan to relieve the climate from the monotony which prevails in Formosa and in the countries which face Japan on the mainland of Asia.

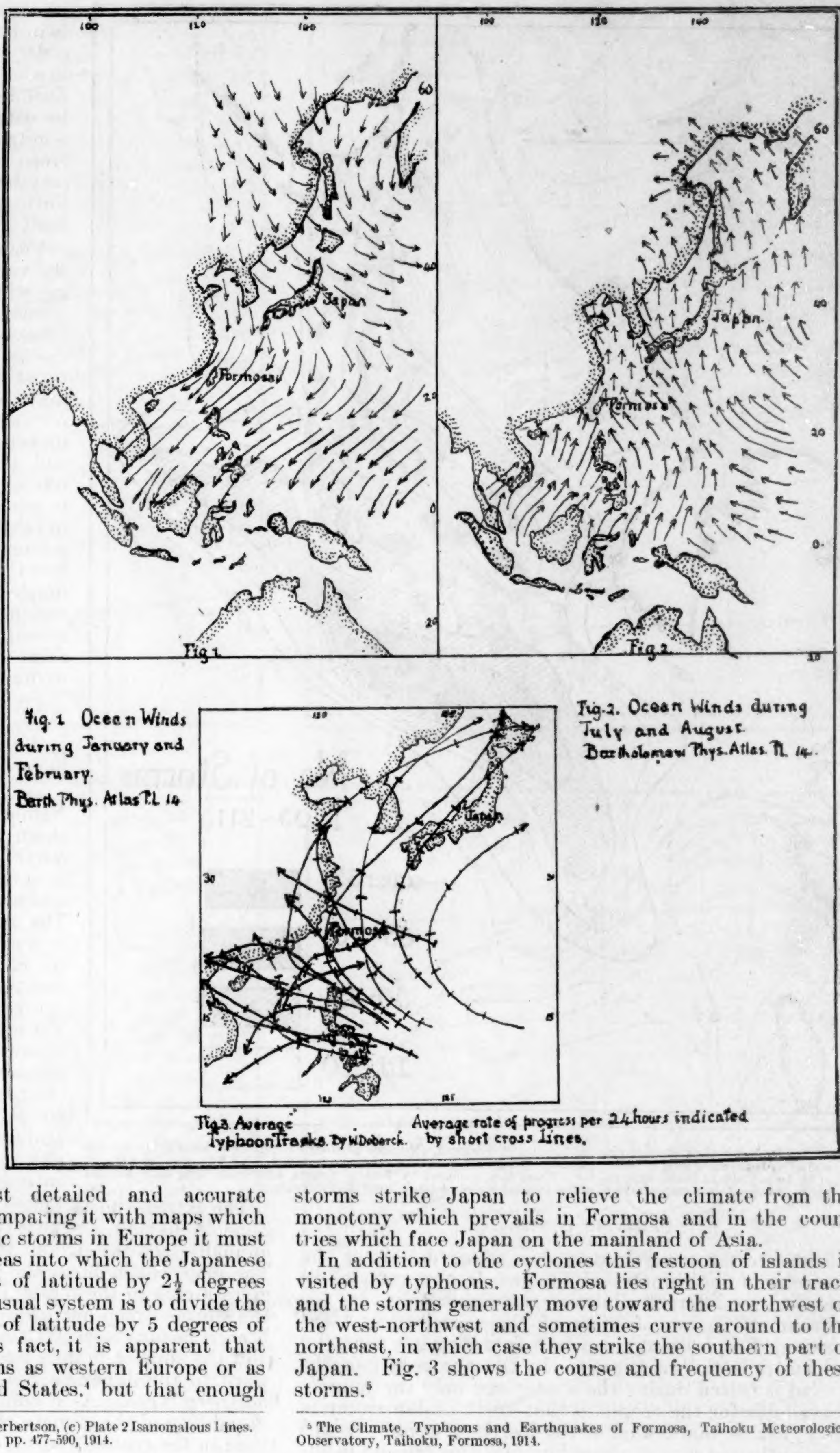


Fig. 1 Ocean Winds during January and February. Barth Phys. Atlas Pl. 14

Fig. 2. Ocean Winds during July and August. Bartholomew Phys. Atlas Pl. 14.

Fig. 3. Average Typhoon Tracks. By W. Doberck. Average rate of progress per 24 hours indicated by short cross lines.

In addition to the cyclones this festoon of islands is visited by typhoons. Formosa lies right in their track and the storms generally move toward the northwest or the west-northwest and sometimes curve around to the northeast, in which case they strike the southern part of Japan. Fig. 3 shows the course and frequency of these storms.[5]

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[3] Atlas of Meteorology, Bartholomew and Herbertson, (c) Plate 2 Isanomalous Lines.
[4] Bull. of the Geol. Soc. of America, Vol. 25, pp. 477–590, 1914.
[5] The Climate, Typhoons and Earthquakes of Formosa, Taihoku Meteorological Observatory, Taihoku, Formosa, 1914.

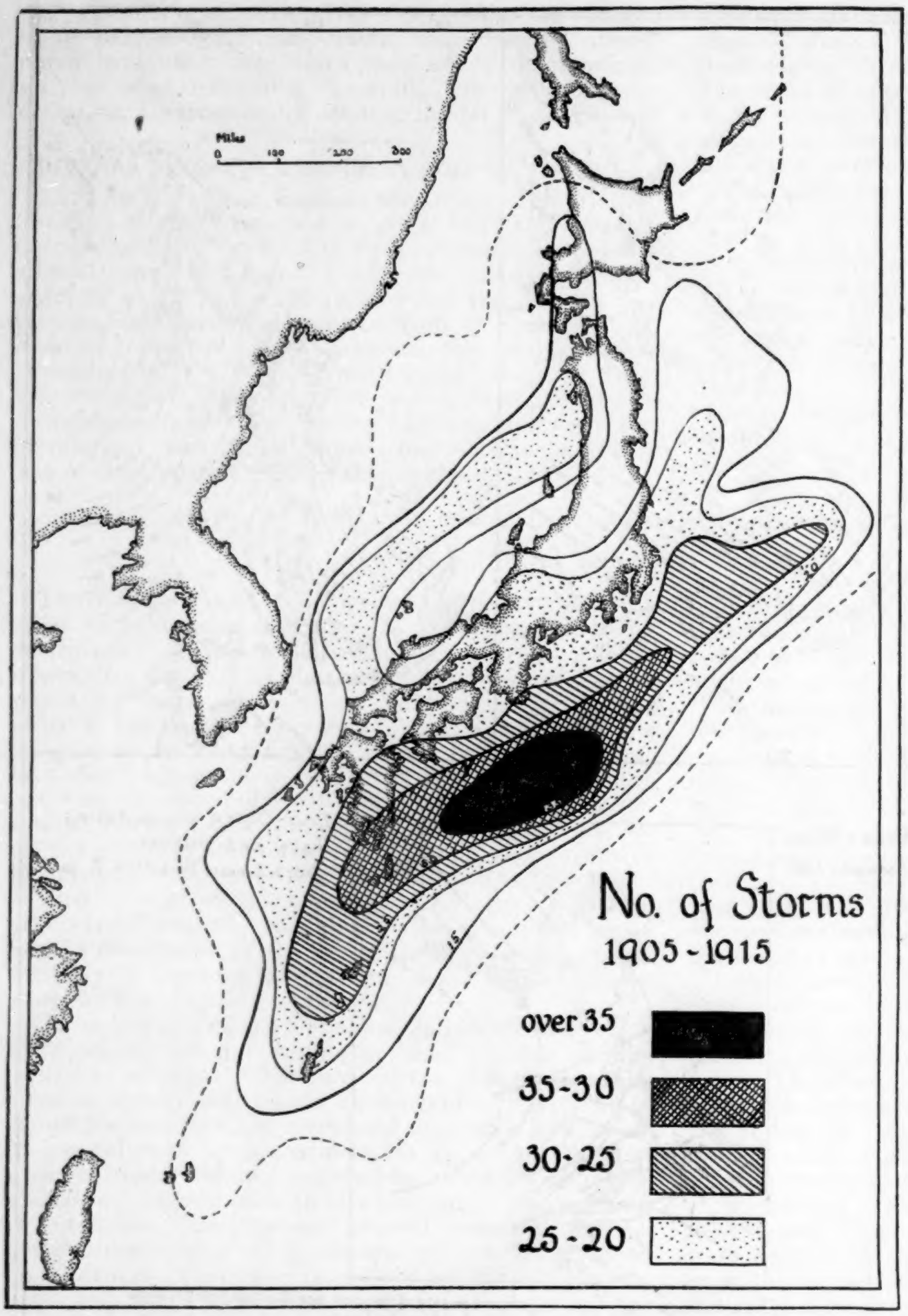


FIG. 15.—Frequency of cyclonic storms in Japan and Formosa. Number of storms occurring in areas 2½° in latitude and 2½° in longitude during 10 years, 1905–1915. (Compiled from data given in art. 4, Vol. XXXVII, of Journal of Coll. of Sc. Imp. Univ. of Tokio, 1916, pp. 6–8. These data prepared by Terada, Yokata, and Otuki from daily weather maps and monthly weather review of the Central Meteorological Observatory, Tokio.)

CLIMATIC ZONES.

Such are the general conditions which determine the character of the climates of Japan. It now remains to consider the different climatic zones separately.

From the point of view of the agriculturist [6] the Japanese Empire is divided into four climatic zones by the winter isotherms (fig. 7). In the northern part the ground is frozen during the winter and only the summer is available for the crops, so that north of Jan. isotherm 32° F. can be marked off as the Northern Zone. As one goes southward winter wheat becomes possible and in the southern part of the central zone two crops a year are the regular order of things, wheat in winter and rice in summer, therefore a Central Zone between 32° F. and 40° F. can be defined. The south of Japan is semitropical, and as many as three crops a year are being raised; this may be termed the Southern Zone. Formosa, being tropical, stands by itself as the fourth climatic zone.

Variations in the rainfall due to the varying direction of the prevailing winds, and difference in the frequency of the cyclonic storms, make necessary certain subdivisions of the two northern of the agriculturist's zones. The Northern Zone may be divided into an extreme northern division, with Nemuro as its type, where the rainfall is scanty, and a southerly division with Hakodate as the type, where the rainfall is greater, and the variability, both in rainfall and temperature, is more pronounced. On the other hand, the Central Zone is divided by a north-south line, into an eastern region which gets summer rain, and a western region which gets winter rain. The other two zones of the agriculturist remain unchanged.

Fig. 17 shows the extent of these zones, and fig. 14 shows temperature and rainfall graphs of typical places in each.

1. *The Northern Zone.*—(*a*) The Nemuro type. In the extreme northern part, comprising the greater part of the island of Yezo, the climate is unusually severe for the latitude and unusually extreme for an island. The average winter temperature is everywhere below 20° F. and winter continues for more than three months, while in the center the average temperature is as low as 12° F. The severe winter is followed by a summer during which the average temperature is as high as 70° F. in the center, and is nowhere less than 60° F. Thus northern Yezo may be said to have a continental climate although it is a small piece of land entirely surrounded by water.

The extreme north differs from the rest of the Northern Zone in having a scanty rainfall; less than 20 inches annually falls throughout the greater part of this region. The map which shows the course of the cyclonic storms gives a clue to the reason for this scarcity of rain; since the storms sweep northward along two tracks, the larger branch passing over Tokyo and so eastward to the ocean, and the smaller branch passing over Niigata and northward to the Japanese Sea, neither branch sweeps over northern Yezo. As a result the rain is scarce and the variability of the climate of the extreme north is far less than in the center.

(*b*) The Hakodate type. As one travels toward the south both winter and summer temperature become less

[6] Outlines of Agriculture in Japan, Agricultural Bureau, Tokyo, 1910.

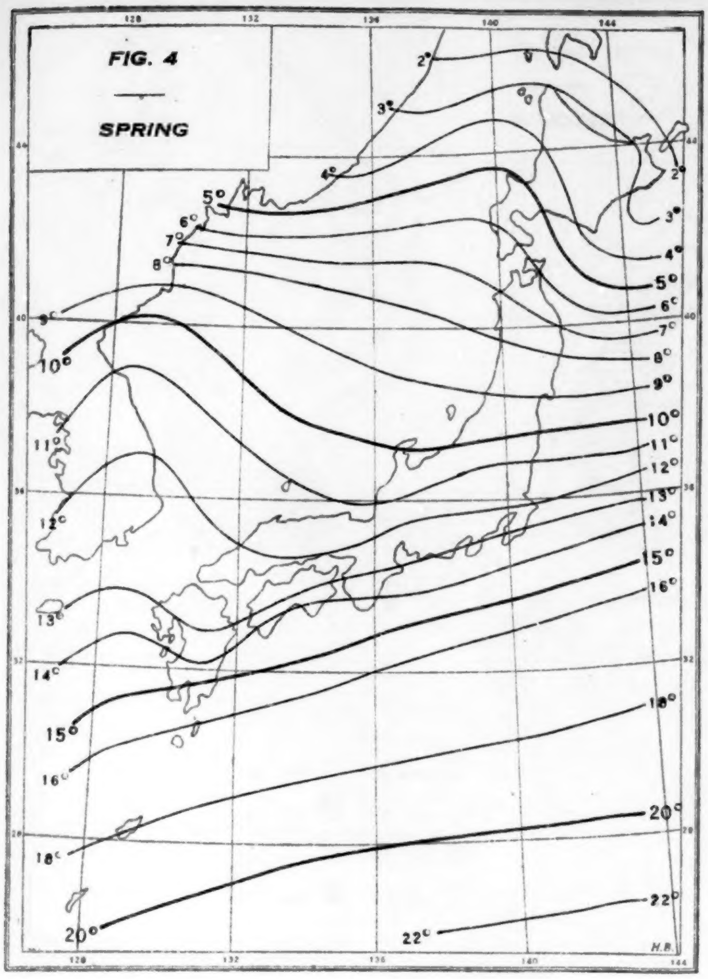


FIG. 4 — SPRING

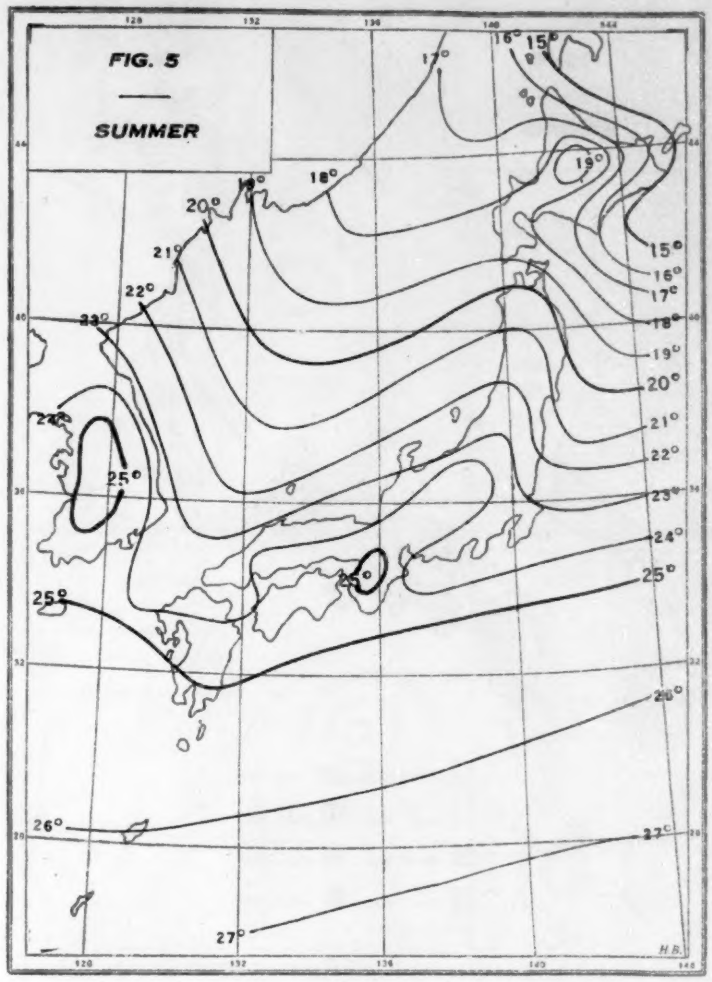


FIG. 5 — SUMMER

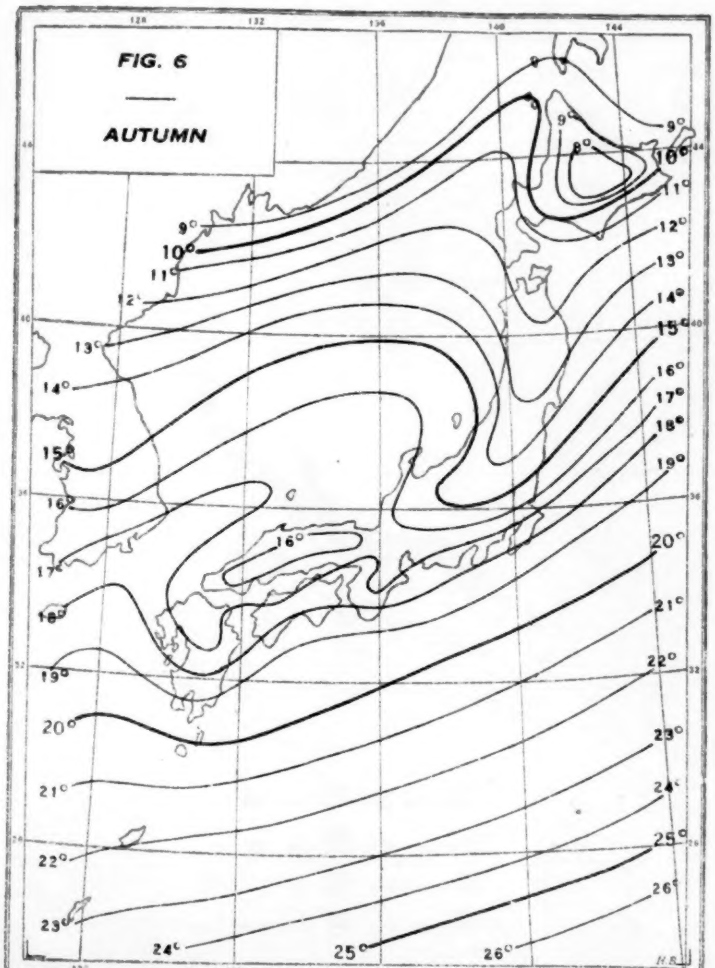


FIG. 6 — AUTUMN

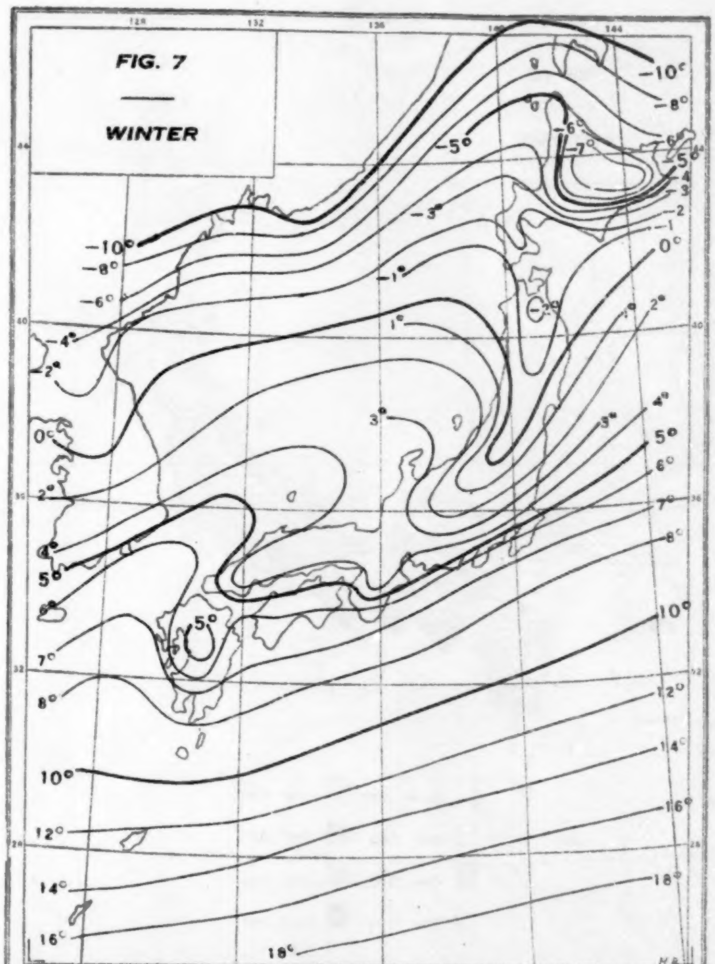


FIG. 7 — WINTER

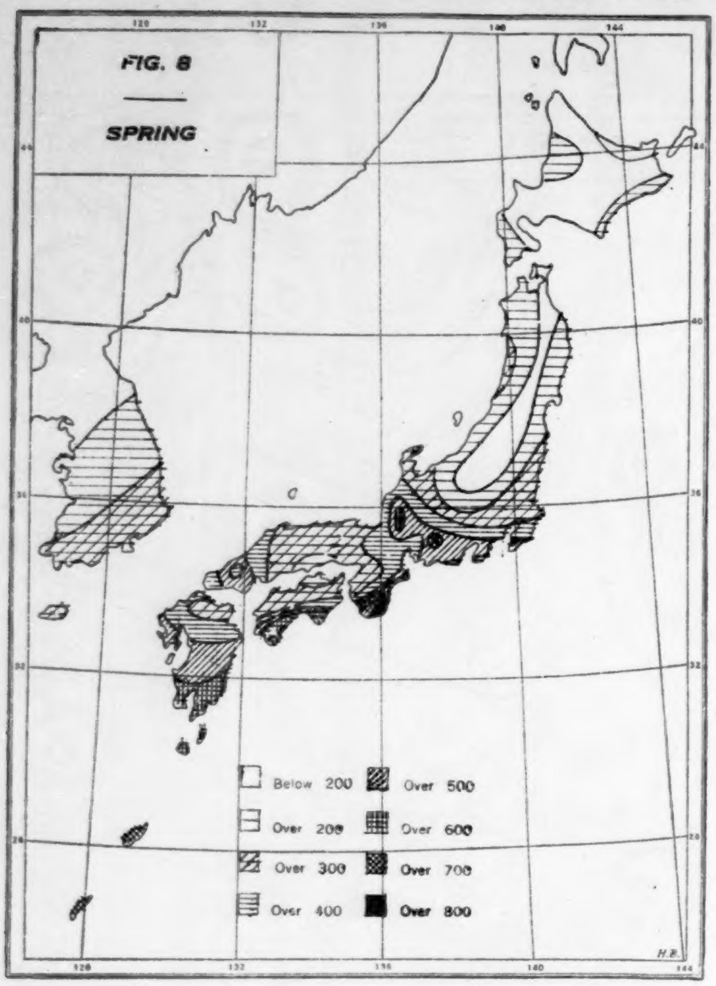


FIG. 8
SPRING
Below 200
Over 200
Over 300
Over 400
Over 500
Over 600
Over 700
Over 800
H.B.

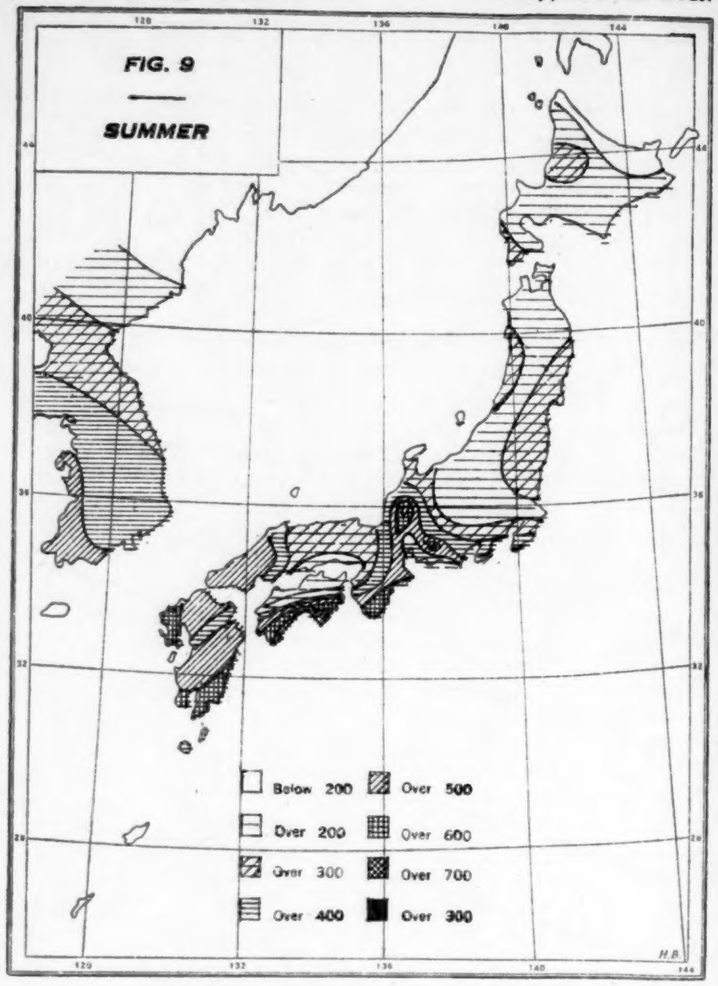


FIG. 9
SUMMER
Below 200
Over 200
Over 300
Over 400
Over 500
Over 600
Over 700
Over 300
H.B.

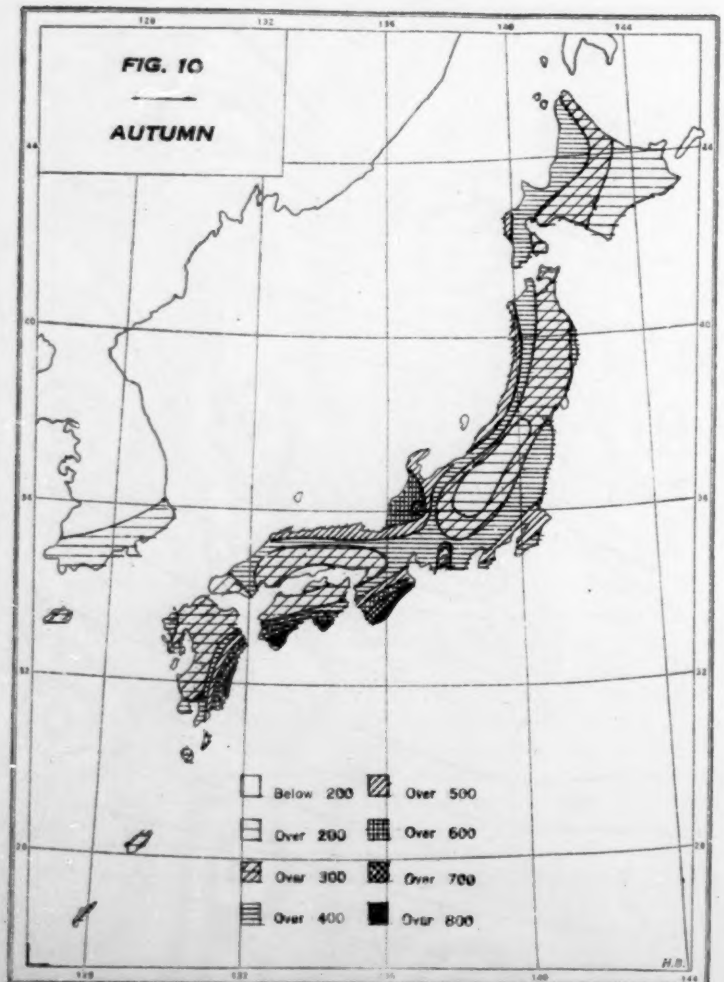


FIG. 10
AUTUMN
Below 200
Over 200
Over 300
Over 400
Over 500
Over 600
Over 700
Over 800
H.B.

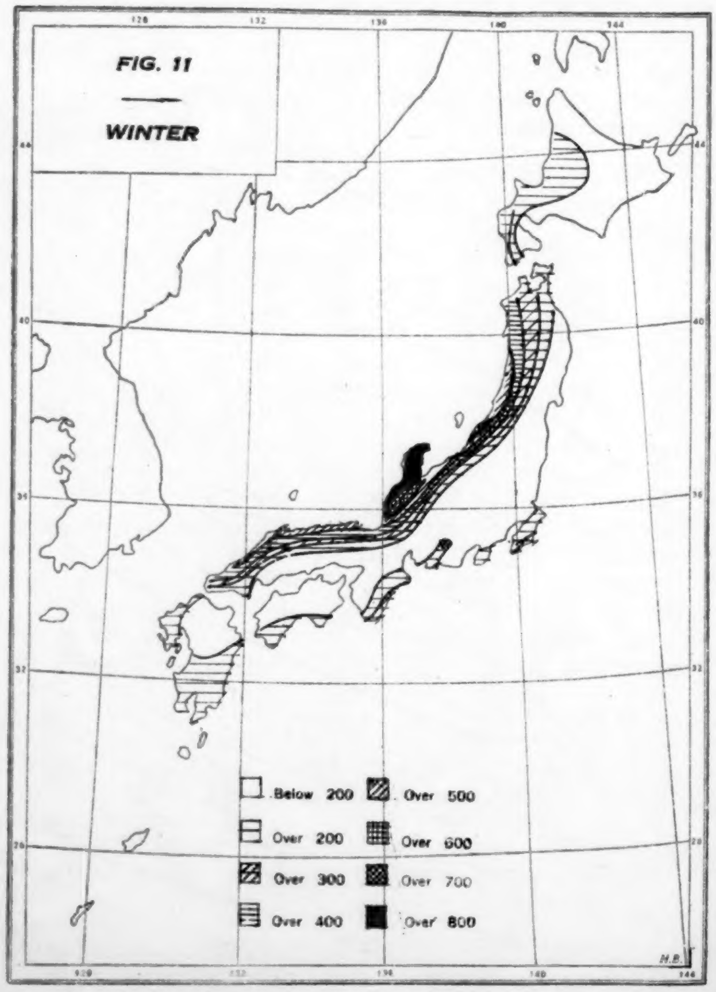


FIG. 11
WINTER
Below 200
Over 200
Over 300
Over 400
Over 500
Over 600
Over 700
Over 800
H.B.

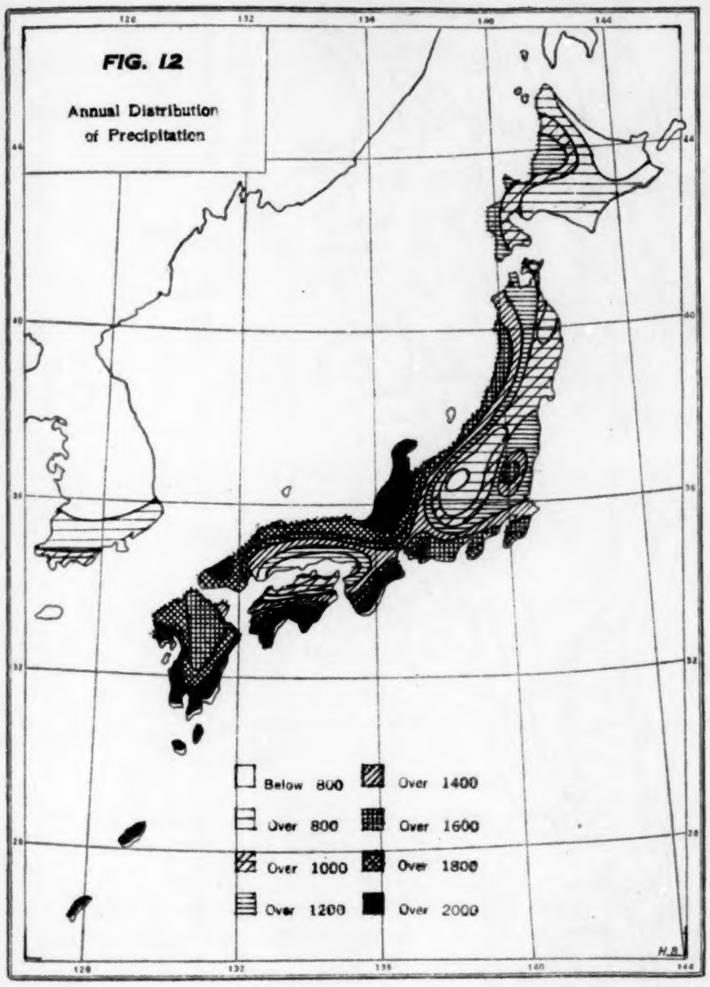


FIG. 12

Annual Distribution of Precipitation

FIG. 16

Progress of 0° Isotherm Toward the South

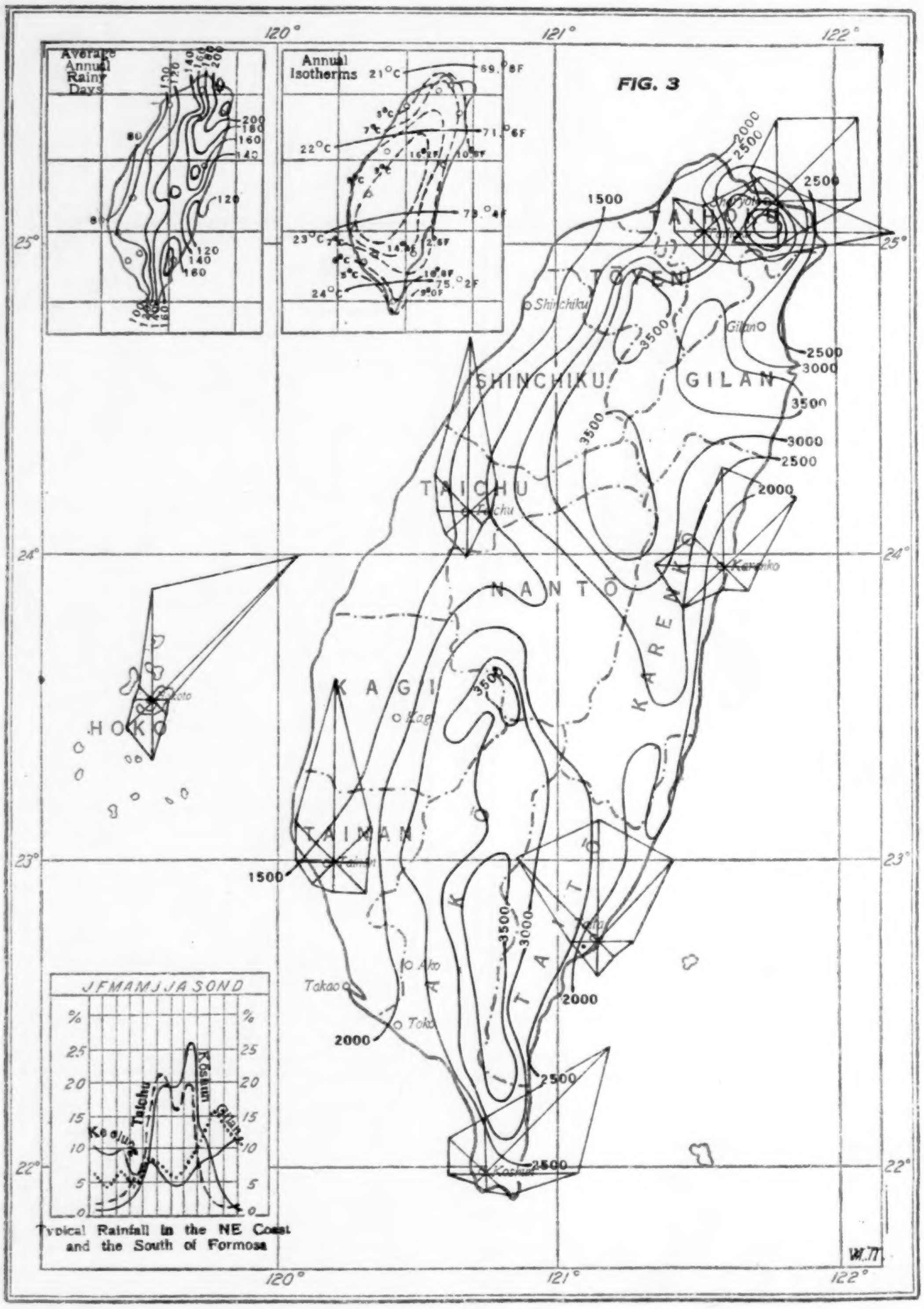


FIG. 3
120°
121°
122°
25°
24°
23°
22°
Average Annual Rainy Days
Annual Isotherms
21°C
22°C
23°C
24°C
TAIHOKU
TOYEN
SHINCHIKU
GILAN
TAICHU
NANTO
KAREN
KAGI
HOKO
TAINAN
TAITO
Shinchiku
Gilan
Taichu
Karenko
Kagi
Tainan
Ako
Takao
Toko
Koshun
1500
2000
2500
3000
3500
J F M A M J J A S O N D
%
25
20
15
10
5
0
Keelung
Taichu
Koshun
Typical Rainfall in the NE Coast and the South of Formosa
W.T.

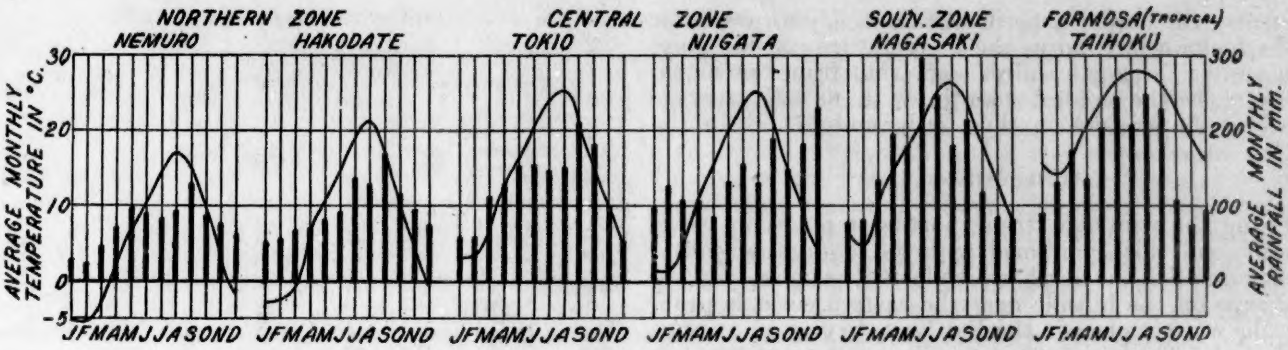


FIG. 14.—Average monthly temperature (solid lines) and rainfall curves (vertical bars) of typical places in each zone.

extreme, as is shown in figs. 5 and 7, and the rainfall increases, as is shown in figs. 12 and 14. More storms are received, as is shown in fig. 15, and this accounts both for the increase in the rainfall and for the greater variability of the climate.

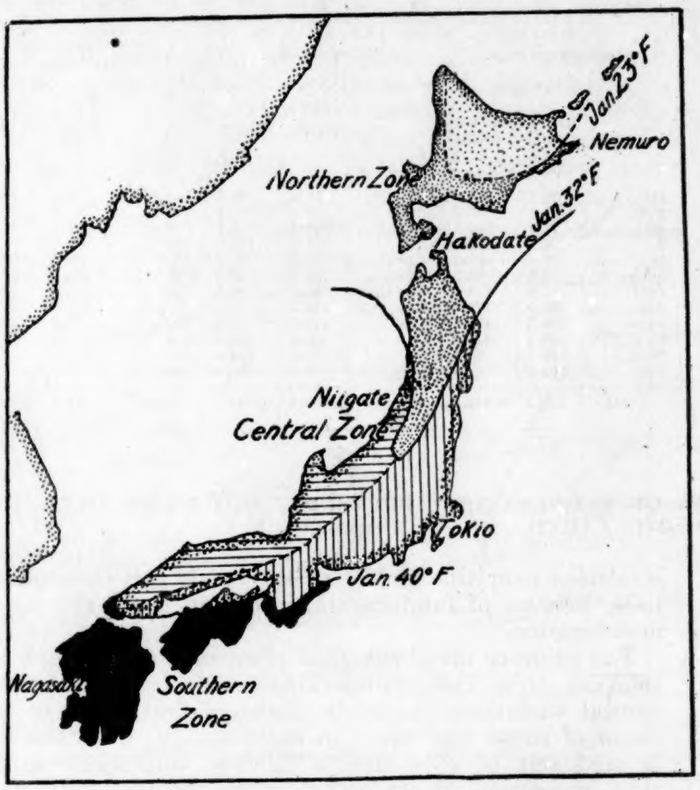


FIG. 17.—Map showing climatic zones. (Isotherms after Tokio Central Meteorological Observatory, Tokio.)

2. *The Central Zone.*—(*a*) The Tokyo type. This zone comes nearest to the optimum both in temperature and humidity (as defined by Prof. Huntington),[7] as well as being the most variable on account of the storms. It is interesting to note that this zone includes the most progressive part of Japan where manufactures are springing up, where trade is most vigorous, where the university is the oldest and most energetic, and where the seat of government is situated.

The central part of the eastern coastal strip of Japan is a good deal warmer in winter than corresponding regions on the opposite coast (fig. 7). This can perhaps be explained as the influence of the Kuroshio and the protecting backbone of mountains which shelter the coastal strip from the bitter winds from Siberia, and cause it to have fine clear weather during the greater part of the winter. It is, however, cold enough for snow to fall in all parts and to lie upon the ground even in the south. The relief is of the greatest assistance to the farmers since the sheltered slopes face southward and thus get greater insolation. The cyclonic storms are most frequent in this part (fig. 15) and account in part for the heavy summer rainfall, the noticeable dip in the rainfall graph during the summer months being due to the fact that the cyclonic storms are less frequent in July than in June or August.[8] Ranges of high mountains running parallel to the coast receive the full force of the prevailing winds from the ocean and cause this coastal strip to be one of the rainiest parts of Japan.

(*b*) The Niigata type. The western coastal region does not differ greatly in temperature from that of the eastern coast, but most people would find it a much less agreeable climate, since it gets far more rain and fog, and less bright sunshine. In winter, during the regular rainy season, not a day passes without some rain or snow brought by the bitter northwest winds, and in summer the cyclonic storms bring a good deal of rain, the same double maximum being noted as in the Tokyo graph.

3. *The Southern Zone.*—This zone is semitropical. Its average winter temperature is over 40° F. The climate is warmer than that of the Central Zone although snow falls in the winter and sometimes lies on the ground. Its average summer temperature is between 75° and 80° which is rendered enervating by its great humidity. The rainfall is very heavy, being over 80 inches a year north coast, the greater part comes in summer. Cyclonic storms are numerous and the variability, though less than the Tokyo type, is still considerable, so that its climate is far more stimulating than that of Formosa.

4. *Formosa.*[9]—Formosa is situated on the Tropic of Cancer and has a tropical climate. The summers are long and are accompanied by intense heat. The transition from summer to winter is very rapid, the warm season coming quickly after the cold months. The winters are short and no severe cold is known although high mountain peaks are snow capped; frost, as a rule, is unknown on the lower levels.

In Formosa the year is divided into two seasons; summer from April to October and winter from November to March.

The mean monthly temperature of January is in the coolest parts over 60° F. June to September is the hottest part of the year, the mean monthly temperature ranging between 79° and 82° F. No marked variation between north and south is seen during these months. The daily maximum will often rise above 86° F. and continue so for a whole month. Sometimes the east

[7] World Power and Evolution, Ellsworth Huntington, New Haven, 1919, pp. 58-104.

[8] Atlas of Meteorology, plate 28.

[9] The Climate, Typhoons and Earthquakes of Formosa, Taihoku Meteorological Observatory, Taihoku, Formosa, 1914.

coast near the border experiences a hot, dry wind similar to the foehn, which raises the temperature considerably.

In winter the north differs somewhat from the south. February is the coldest month, with 68° F. average monthly temperature in the south, and 57° F. in the north.

WIND AND RAIN.

During the winter a strong northeast monsoon blows steadily and this, combined with the mountains, causes heavy rainfall in the north, which lasts for several months. Kashoryo on the hillside near the eastern coast is probably the wettest place in the Far East, having an average rainfall of 7,338 mm. (289 in.). The west coast gets less rain because it is protected by the mountains.

During the summer the southwestern monsoon prevails, and except during the occurrence of a typhoon the winds are light. Frequent thunderstorms give abundant rainfall, and a typhoon will bring several hundred mm. of rain on a single day.

Formosa lies in the highway of the great storms known as typhoons. These storms originate in the sea surrounded by the Philippines, the west Carolines, and the Mariana Islands, or else in the China Sea itself.

The earliest typhoons that visit Formosa occur in May and the latest in November, and sometimes from December to April there are none. August is the month when they generally occur, and their frequency may be judged from the fact that in the 17 years from 1897 to 1913 there were 30 remarkably severe typhoons; 15 of these occurred in August.

The storms move generally toward the northwest or west-northwest, and the northern half of the island of Formosa is directly in that district. The force of the wind is terrific, and there is generally a corresponding ocean swell which is felt on the southwest coast.

Fig. 13 (Chart XV) epitomizes the characteristics of the climate of Formosa.

Average monthly temperature in °C.

(1) Northern zone.			(2) Central zone.			(3) Southern zone. (4) Formosa (tropical zone)		
	Nemuro.	Hakodate.		Tokio.	Niigata.		(3) Nagasaki.	(4) Taikoku.
Jan	−5.1	−3.1	Jan	3.0	1.5	Jan	6.0	15.7
Feb	−5.5	−2.6	Feb	3.5	1.2	Feb	4.4	14.0
Mar	−2.5	0.7	Mar	6.8	4.5	Mar	9.2	16.9
Apr	3.0	6.4	Apr	12.6	10.4	Apr	14.4	20.7
May	6.6	10.4	May	16.5	15.0	May	17.9	23.8
June	9.8	14.2	June	20.4	19.3	June	21.6	26.6
July	14.1	18.5	July	23.8	23.5	July	25.5	27.9
Aug	17.2	21.3	Aug	25.4	25.5	Aug	26.6	27.7
Sept	15.1	17.4	Sept	21.8	21.3	Sept	23.4	26.2
Oct	10.4	11.4	Oct	15.8	15.1	Oct	18.8	23.3
Nov	4.3	5.3	Nov	10.3	9.4	Nov	12.8	19.6
Dec	−1.4	−0.3	Dec	5.3	4.1	Dec	7.9	16.7
No. of years of observation	33	40	No. of years of observation	37	31	No. of years of observation	34	18

Average monthly rainfall in mm.

(1) Northern zone.			(2) Central zone.			(3) Southern zone. (4) Formosa (tropical zone).		
	Nemuro.	Hakodate.		Tokio.	Niigata		(3) Nagasaki.	(4) Taikoku.
Jan	28.5	55.8	Jan	57.1	96.3	Jan	78.9	91.0
Feb	21.1	57.7	Feb	58.0	125.2	Feb	81.7	130.7
Mar	43.7	64.1	Mar	109.2	104.6	Mar	130.1	175.8
Apr	70.2	69.3	Apr	131.8	106.0	Apr	196.6	137.6
May	97.7	80.1	May	156.9	82.8	May	180.1	204.9
June	90.6	89.9	June	153.8	132.9	June	294.9	241.2
July	85.9	138.0	July	143.3	156.9	July	245.3	207.0
Aug	94.0	129.3	Aug	145.2	130.9	Aug	177.5	246.9
Sept	134.5	168.4	Sept	210.6	186.6	Sept	210.9	233.2
Oct	88.1	114.3	Oct	180.1	146.3	Oct	117.6	102.7
Nov	79.2	95.8	Nov	100.3	182.5	Nov	85.4	72.6
Dec	62.0	79.3	Dec	54.1	232.6	Dec	85.4	93.1
Total	825.7	1,142.0	Total	1,500.4	1,793.5	Total	1,884.4	1,940.1

HISTORICAL NOTE ON CHARTS OF THE DISTRIBUTION OF TEMPERATURE, PRESSURE, AND WINDS OVER THE SURFACE OF THE EARTH.

The state of the atmosphere at any given point is completely determined when we have given the values at that point of the six *meteorological elements*—temperature, pressure, wind, humidity, cloud, and precipitation (electrical state has no influence on the phenomena we are considering). The day to day fluctuations of these elements, caused by disturbances in the atmosphere, constitute *weather*, whereas the "normal" values, obtained by averaging a very long series of observations in order to eliminate the chance irregularities, largely characterize the *climate*. The varying climate found at different localities over a wide area is most conveniently represented graphically by means of isometric charts.

For purposes of theoretical and dynamical meteorology, it is essential to have such charts for the entire globe, without, however, going into any minute climatological details. "Normal" values have but little significance or utility for practical meteorology, other than descriptive climatology, as pointed out, *e. g.*, by J. Rouch, *Préparations Météorologiques pour les Voyages Aériens*, Paris, 1920.

Meteorological phenomena are all due to the flood of energy received from the sun; hence the measurement of the amount of *solar radiation*, and the distribution of *insolation* over the surface of the earth and throughout time, become of fundamental importance as subjects of investigation.[1]

The primary meteorological phenomenon to which insolation gives rise—temperature, and its diurnal and annual variations—must be assigned first place in the chain of cause and effect in meteorology; were the sun blotted out of existence, a lifeless uniformity would take possession of the earth; were the distribution of temperature over the earth always the same and the temperature uniform, a calm equilibrium would ensue.[2] The temperature, pressure, and prevailing winds, because of their intimate relations with one another, are best dealt with together; taken in conjunction with the topography, etc., they determine the distribution of the remaining elements, and the climatological characteristics of any region.

[1] *Cf.* C. Dorno, On Observations of Solar and Sky Radiations and Their Importance to Climatology and Biology and also to Geophysics and Astronomy, MONTHLY WEATHER REVIEW, 48, 18–24, 1920; J. B. Kincer, Sunshine in the United States, MONTHLY WEATHER REVIEW, 48, 12–17, 1920; H. H. Kimball, Variations in the total and luminous Solar Radiation with Geographical position in the United States, MONTHLY WEATHER REVIEW, 47, 769–793, 1919; *Annals of the Astrophysical Observatory of the Smithsonian Institution*, vols. 1–3.

[2] Laplace, *Méc. Cél.*, Bk. 1, Art. 37; Bk. 3, chap. vii. Ferrel, *Rept. U. S. Coast Survey*, 1875, p. 402; W. J. Humphreys, *Physics of the Air*, chap. vii.

Meteorological phenomena were undoubtedly among the first to be noticed by primitive man. The general distribution of temperature over the world has been known since antiquity—Eratosthenes, Polybius, and Strabo were acquainted with the cause of this distribution; long before comparable thermometers were known, or a precise idea of the mean temperature had been formulated, Halley, in 1693, laid the foundations of the theory of the heating power of the sun at different latitudes; in the eighteenth century, Mairan and Lambert wrote on the same subject; Mayer's empiric fomula for determining the mean temperature at any latitude, once the constants had been found by observations at a few stations, played an important rôle for many years.

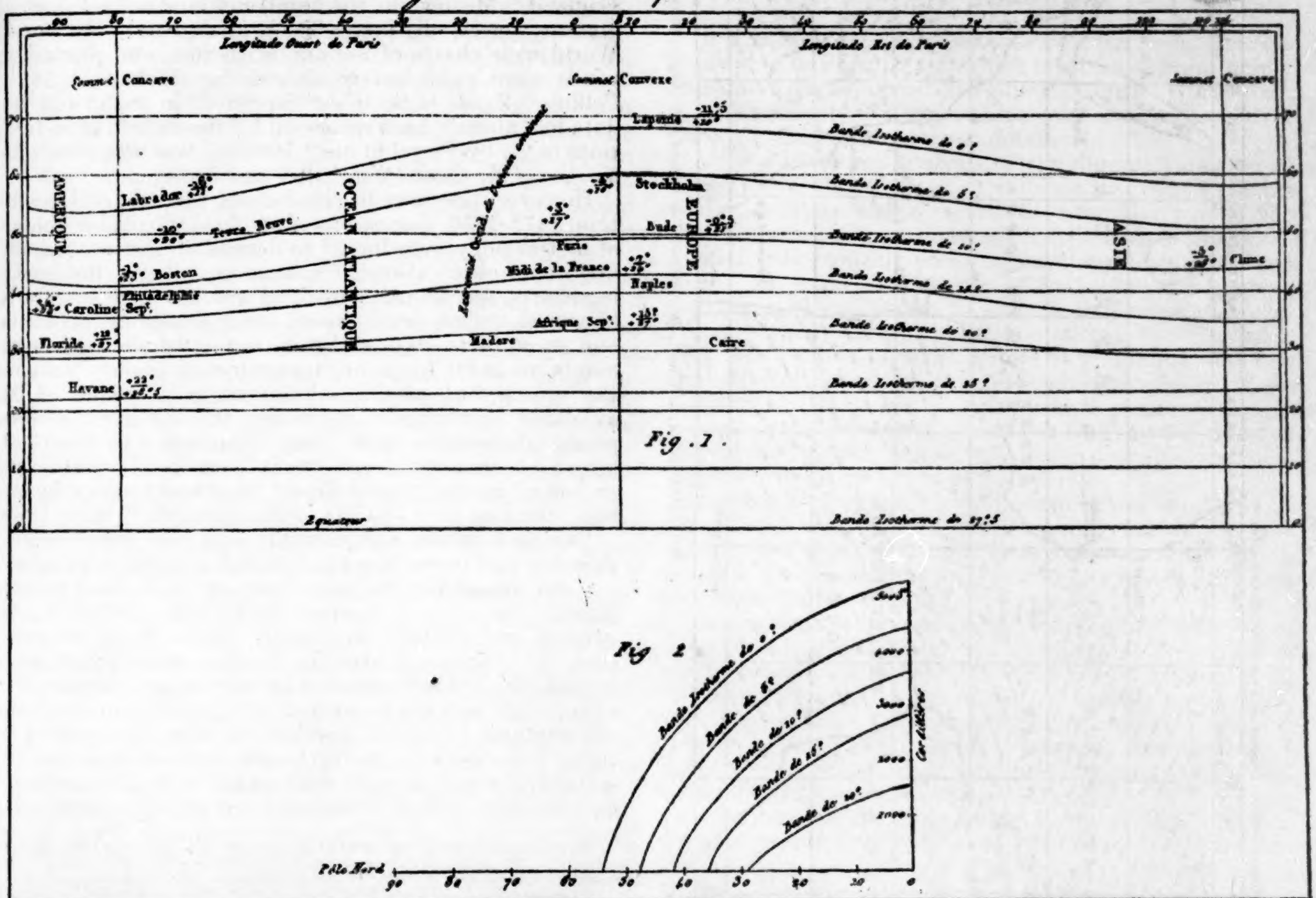
The monsoons of the Indian Ocean have also been known since the earliest times, having been described by Aristotle and the early Arabs; the trades were discovered by Columbus, and their distribution mapped out by the navigators of the sixteenth century. The seventeenth century witnessed the discovery by Torricelli of the barometric pressure of the atmosphere, and its decrease with elevation. Before the exploring expeditions led by Capt. Wilkes and by Sir James Ross (both about 1840), it was pretty generally thought that the barometric pressure at sea level is normally nearly or quite the same at all places—about 30 inches; these expeditions clearly demonstrated that the barometer persistently stood low in the Tropics, higher to either side of the tropical zone, and lower again toward the poles.[3]

Somewhat previous to the opening of the nineteenth century, there was inaugurated a period in the history of meteorology which was marked by the attempt to give logical explanations for the various phenomena. In spite of the great mass of weather lore and observational facts accumulated since the time of the ancients, there had been little or no attempt at a rational theory of meteorological phenomena in general. But meanwhile the sciences of mathematics, physics, hydrodynamics, etc., had been developing; and at the beginning of the nineteenth century, with the chemical nature of the atmosphere at last known, the Gas Laws discovered, and the equations of analytical mechanics available, it became possible to found the science of Dynamical Meteorology. The first theoretical investigation of the atmosphere from this standpoint was given by Laplace (*l. c.*) in the Mécanique Céleste, which contains practically all the then existing knowledge of the subjects treated. His meteorological contributions, however, relate only to an atmosphere in equilibrium, and to atmospheric tides.

Increasingly accurate and extensive observation also marked this period. The first temperature chart (as

[3] More recent observations have established that in the vicinity of the poles themselves the barometer again stands high.

Carte des lignes Isothermes par M. A. de Humboldt Pl. XXIII.

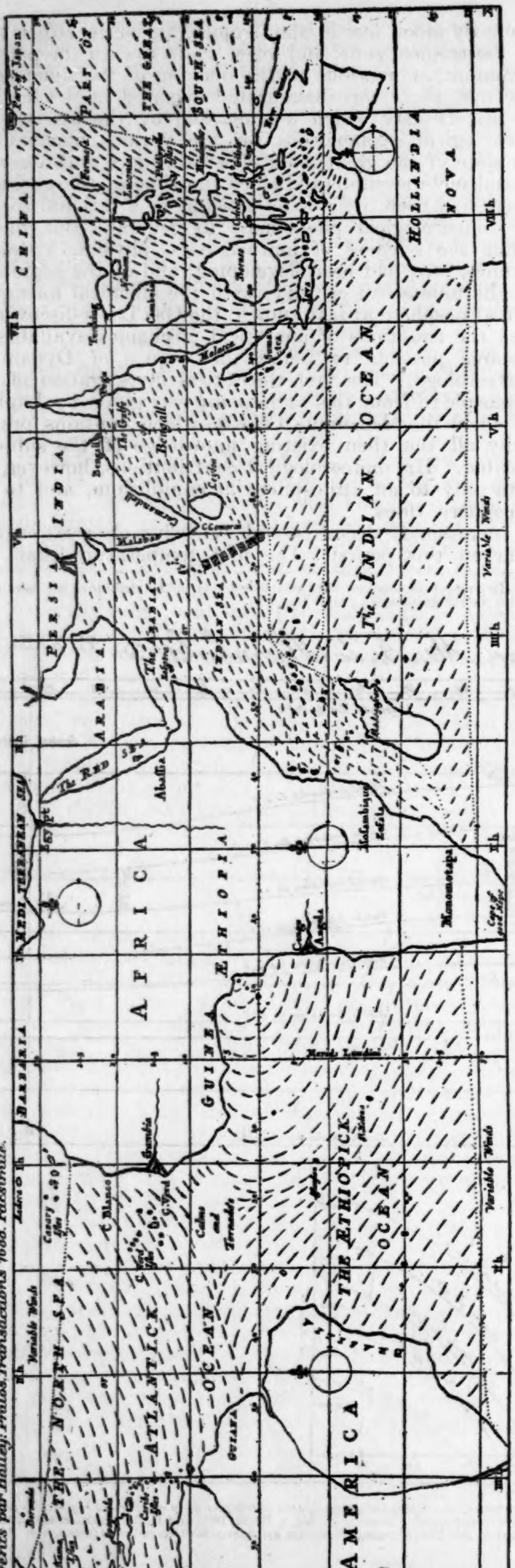


Gravé par Adam.

VON HUMBOLDT'S Isothermal Chart of the Globe, 1817. First published in the author's reprints of *Des lignes isothermes et de la distribution de la chaleur sur le globe*, Mémoires de physiques et de chimie de la Société d'Arcueil. T. III. p. 462–602; reproduced in facsimile in Hellmann's Neudrucke, No. 8, Berlin 1897; and Hildebrandsson and Teisserenc de Bort's "*Les Bases de la Météorologie Dynamique,*" t. I, p. 228, 1907. See also W. Meinardus, *Die Entwickelung der Karten der Jahres-Isothermen von Alexande von Humboldt bis auf Heinrich Wilhelm Dove*, Humboldt-Centenar-Schrift, Berlin, 1899.

Pl. LVII.

Carte des vents par Halley; Philos. Transactions 1688. Facsimile.



HALLEY'S Chart of the Winds, *Philosophical Transactions* 1688. Classic throughout the 18th century.

well as first meteorological isogram chart) published was that of von Humboldt, 1817, who gave the name *isotherms* to the lines which he mapped; he employed records from 58 stations to give the distribution of annual mean temperatures over the globe. Kämtz improved upon this map in 1832, using 145 stations.[4] The next important landmark is the publication, in 1852, of Dove's "*Die Verbreitung der Wärme auf der Oberfläche der Erde,*" in which he, realizing the inadequacy of annual isotherms, first constructed isothermal charts of the globe for each month, employing records from 900 stations. The first chart of prevailing winds was that published by Halley in the *Philosophical Transactions*, 1688. This map remained classic throughout the eighteenth century; and not until well into the nineteenth century, when the need for the shortest possible sailing routes across the ocean arose, were further advances made.

Although theoretical isobars, in the form of straight lines parallel to the equator, had been drawn by H. K. W. Berghaus in 1839, the first isobaric chart based upon observational data was that of France and adjacent region published by Renou in 1864;[5] the first world chart was Buchan's, 1868.

The efforts of Maury finally succeeded in enlisting the cooperation of seafaring men, and led to the international congress at Brussels in 1853, at which a uniform plan for the utilization of marine observations, especially of winds, for the making of charts was agreed upon. The well-known "*Track and Pilot Charts*" resulted; while similar charts were published by France, Germany, and England. Meanwhile, the number of land meteorological stations was rapidly increasing in all regions of the world. World wide charts of isobars, isotherms, and prevailing winds were published by Alexander Buchan in 1871; Coffin's "*Winds of the Globe*" appeared in 1875; and the data had already been employed for theoretical investigations, *e. g.*, by Ferrel in his "*Meteorological Researches for the Use of the Coast Pilot,*" 1877 and earlier.

However, previous to the famous Challenger Expedition, 1872–1876, discussions of the fundamental problems of meteorology were forced to depend almost exclusively upon land observations; furthermore, all the then existing charts, mentioned above and which now possess only historical value, were based on necessarily defective and incomplete data. Hence, not only were arrangements made for frequent meteorological observations on the cruise, but also a subsequent rediscussion of all available information regarding the different atmospheric phenomena, with especial reference to the Challenger observations, was carried out by Buchan, and embodied in the great "*Report on Atmospheric Circulation*" forming pt. v. vol. II of the *Scientific Results*, 1889.

Buchan's annual and monthly charts of temperature, pressure, and prevailing winds, which are still in standard use, are based for the most part on land observations during the 15-year period 1870–1884, inclusive. In tropical and subtropical regions, where the mean pressure, etc., varies but little for the same month from year to year, it is not so important for purposes of comparative climatology and the construction of world maps that the observations be rigidly confined to the same period of time; but elsewhere, owing to the more or less marked instability which prevails with regard to the meteorological elements, *it is of the utmost importance to obtain series*

[4] Kämtz confirmed the existence of two "poles of cold," the existence of which had been suspected in 1820 by Brewster, who, from a study of Humboldt's chart, had come to the conclusion that the geographical poles were not the places of minimum temperature.

[5] Fuller historical information, with references to original literature, and facsimiles of maps, will be found in H. Hildebrandsson and L. Teisserenc de Bort, *Les Bases de la Météorologie Dynamique*, t. 1, 1907, pp. 185–228. See, in addition, C. F. Talman, List of Meteorological Isograms, MONTHLY WEATHER REVIEW, 43, 195–198, 1915.

of observations covering, or capable of being reduced to, the same period of observation." Buchan used 1,366 stations for the pressure maps, 1,620 for temperature, and 746 for the winds, the whole embodying all the information existing, every source being drawn upon.

The first attempt at a systematic atlas of meteorology was the meteorological section of the *Berghaus Physical Atlas*, first published in 1887, and revised in 1895. In 1899 appeared vol. III, *Meteorology*, of *Bartholomew's Physical Atlas*. The charts presented in the latter are chiefly those of Buchan. No attempt has ever been made to utilize the accumulated observations since the publication of Buchan's charts in anything like so comprehensive a manner as was done by him. New, and slightly modified, maps for January, July, and the year have been drawn by Hann, and in their latest form are found in his *Lehrbuch der Meteorologie*, 2d and 3d editions. Detailed charts of various countries, based on the greater part of the vast mass of data now available, have been issued by the several meteorological services; but these are not usually strictly comparable with one another. Indeed, vast as the existing body of observational material is, it is in such form that in its entirety it is available to no one, and would not be manageable by any single person even if it were available to him; a digest of all existing climatological data is urgently needed, and the preparation of such a digest, if properly managed, would be a perfectly feasible task. Many of the best regional maps are reproduced in *Bartholomew's Atlas* (*l. c.*), and some issued later are readily obtainable from the meteorological services of the respective countries. In addition there may be mentioned: Rykatchev, *Atlas Climatologique de l'Empire de Russie*, St. Petersburg, 1900; Ekholm, *Sveriges temperaturforhallanden jamforda med det ofriga Europas*, Ymer, 1899; Teisserenc de Bort, *Annales du Bur. Cent. Met.*, 1881, vol. IV, pp. 1-13, Paris, 1883; and the publications of the recent polar expeditions, *e. g.*, Mohn, *Norwegian North Polar Expedition*, vol. VI, 1905 and Simpson, *British Antarctic Expedition, Meteorology*, vol. I, 1919; H. C. Dunwoody, *Summary of the International Meteorological Observations* (1878-1887, incl.), U. S. Weather Bureau Bull. A, 1893.

The best existing maps for France and adjacent regions are those of A. Angot in his *Études sur la climat de la France* (temperature, *Ann. Bur. Cent.*, 1903; pressure, *ibid.*, 1906; winds, *ibid.*, 1907), based on the data 1851-1900. The best available charts for Europe in general, and especially for Poland, are those in two notable publications, recently received from the latter country, by Gorczynski,[6] also for the period 1851-1900. New maps for the entire globe are also presented in these latter books, but the data used are not so reliable, particularly as regards homogeneity.

A very excellent series of small world charts is contained in the British Meteorological Office's *Barometer Manual for the Use of Seamen*, 9th ed., 1919; they are based on most of the data at present available.

The mapping of the ocean areas presents problems of its own. The isograms of the North Atlantic on Buchan's charts were based on the published international observations; those for the other oceans depended mainly upon coastal and island observations; the collection of marine meteorological data has gone steadily forward since the international congress of 1853, and has been continually utilized for the construction of marine meteorological charts published by the governments of the various maritime nations. In 1909 the U. S. Weather Bureau commenced the publication of a series of monthly charts of each ocean, based on practically all available data; after a few years their publication was continued, in a somewhat modified form, by the Hydrographic Office, and they have been reprinted, unchanged, each month since. This series constitutes probably the best of all such charts.

It seems to have fallen to the lot of the Dutch, however, to make the most comprehensive digest of the marine observations. In publication No. 104 of the Koninklijk Nederlandsch Meteorologisch Instituut appear monthly charts of the Indian Ocean utilizing the observations made from 1856-1912; and similar charts for the North Atlantic are now in process of publication.[7]

Special mention should also be made of the unique (and only) marine meteorological atlas, *Atlas de Météorologie Maritime, publié à l'occasion de l'Exposition Maritime Internationale*, Paris, 1887; which contains, besides the extensive text, Teisserenc's de Bort's pressure and wind charts of the globe, Brault's wind charts of the North Atlantic, surface water temperature maps, and numerous special charts.—*Edgar W. Woolard.*

[6] Władysław Gorczyński. O Cisnieniu Powietrza w Polsce i w Europie, Warszawa, 1917; and Nowe Izotermy Polski, Europy i kuli Ziemskiej, Warszawa, 1918.

[7] See Kon. Ned. Met. Inst., No. 110, Oceanographische en Meteorologische Waarnemingen in den Atlantischen Oceaan, December, Januari, Februari, 1870-1914; 1,562,463 observations were utilized for this publication. (Reviewed, p. 412, below.)

NEW ISOTHERMAL CHARTS OF POLAND, EUROPE, AND THE GLOBE.

In a notable work by Wadysaw Gorczyński, recently received from Poland,[1] and which must have been largely prepared within sound of the guns during the World War, the distribution of temperature over Poland and over Europe is dealt with in great detail.

After a harmonic analysis of the diurnal variation of temperature at a number of stations in Poland, and at many localities widely scattered over the world, the question of the determination of true means is discussed. Annual and monthly means, and departures from the means, are formed for the period 1851-1900 at numerous stations in Poland and at 26 stations in Europe and Asia. The day-to-day variation of temperature is also discussed. This interdiurnal variation shows two maxima and two minima each year (in Poland these usually occur in January and May and in April and September, respectively); and its 10-year means for long records show a 30-year and 5-year period, the latter probably identical with Schuster's 4.8 year sun-spot period.

Probable errors and mean deviations are treated, and correlations made between the monthly means at one station and those at a number of other stations. Such correlations are greater and extend to greater distances in winter than in summer.

Detailed monthly and annual isothermal charts are then presented for Poland, for Europe, and for the entire globe, based on the data 1851-1900, with references to the literature used. Anomalies, extremes, amplitudes, etc., are charted and discussed. Finally, a detailed treatment of all the different systems of classification of climates which have been proposed is given, and applied to the climatology of Europe and the world. The volume closes with a sketch of the geography and climatology of Poland, having for its object the justification of the claim that Poland is entitled to recognition as a separate and distinct independent country.—*E. W. W.*

[1] W. Gorczyński, Nowe Izotermy Polsi, Europy, i kuli Ziemskie (Nouvelles Isothermes de la Pologne, de l'Europe, et du Globe terrestre), Warsaw, 1918.

9835—20——3

ATMOSPHERIC PRESSURE OVER POLAND, EUROPE, AND THE GLOBE.

A companion volume to that containing Gorczyński's study of the distribution of temperature over Poland, Europe, and the entire globe, is provided by the same author's work, along similar lines, on the atmospheric pressure.[1]

A discussion of the diurnal variation at stations in Poland, and of the formation of true means, is followed by the consideration of some exceptionally long and homogenous records of pressure at several Polish stations. Formulae for the reduction of pressure to sea-level are discussed and simplified tables constructed. Means and departures from the means, 1851–1900, for 800 stations in Europe, and for stations in other parts of the world, are tabulated. Here the author's enthusiasm carries him away, as has been pointed out in a review by C. E. P. Brooks (*Quar. Jour. Roy. Met'l. Soc.*, Apr., 1920, 46, 218:) "In the case of Scotland, alone, for example, he has adopted one hundred and fifty stations direct from a work by the late Dr. A. Buchan. These stations, many of which must be based on very short periods, were corrected by Buchan to the forty-year period 1856–1895, and recorrected by Gorczynski, using in some cases different standard stations for comparison, to the period 1851–1900. One can but think that one-tenth the number of stations in Scotland, well chosen and well distributed, would have been more useful for map drawing. The same procedure has been applied to records for other countries. The method of reducing a short series to a long one by differences is admirable in itself, but its repeated application to the same set of figures must be condemned." In addition the means calculated for certain isolated stations must often be regarded as doubtful.

Mean and interdiurnal variability, general atmospheric circulation, correlation as applied to studies of pressure and temperature, etc., are treated. The volume is closed by 54 charts, showing the monthly and annual isobars of Poland, Europe, and the world. These are undoubtedly the best now available for Poland and central Europe, joining onto Angot's for the same period, 1851–1900, in France and adjacent regions.—*E. W. W.*

[1] Władysław Gorczyński, O Cisnieniu Powietrza w Polsce i w Europie (Pression atmospherique en Pologne et en Europe). Warsaw, 1917.

OCEANOGRAPHIC AND METEOROLOGICAL OBSERVATIONS IN THE ATLANTIC OCEAN, DECEMBER, JANUARY, FEBRUARY, 1870–1914.[1]

The first requirement in making studies of the variations of ocean currents, water temperatures, air temperatures, pressures and winds, is a reliable set of normal values as a basis of comparison. The Royal Netherlands Meteorological Institute which has always been a leader in the publication of marine data has now provided an excellent series of charts which may be used as a firm foundation for much needed studies of ocean temperature departures and their relations to air temperature, pressure, and wind departures from the normal.[2]

The preface by Director E. van Everdingen is as follows:[3]

"Although observations made during the last 70 years on board Dutch vessels in the North and South Atlantic have been often utilized for publications on oceanography and marine meteorology, they have not been treated in accordance with the requirements of modern science and navigation.

"Only the work dealing with observations made in the region of the Guinea current (Pub. No. 95, 1904) can be considered as being profound from both the theoretical and the practical point of view.

"Yet this publication gives only for a small part of the ocean a summary of the movements of the atmosphere and of the ocean, the mean values of the atmospheric pressure, and of the temperatures of the air and the water.

"Other existing works date for the most part from the days of sailing ships and retain only a very special value.

"In addition, the number of observations at our disposal has enormously increased, and there can be computed much more exactly the mean values of the atmospheric pressure, the temperatures of the air and the water, and the direction and force of the wind and the currents for all regions of the ocean between 50 degrees north and 50 degrees south latitude, with much profit to science as well as to navigation.

"With the completion of the great work on the oceanography and marine meteorology of the Indian Ocean (Pub. No. 104), there has been undertaken a similar work for the Atlantic, of which the first part herewith appears.

"For the most part, the observations made on board Dutch vessels during the years 1870 to 1914 have served as the basis of the work; in addition, thanks to the greatly appreciated collaboration of the "Deutsche Seewarte" at Hamburg and of the "Meteorological Office" at London, it was possible to utilize observations of the wind and the currents in regions where Dutch observations are scarce.

"Abnormal conditions made it impossible to publish simultaneously the atlas and also the tables which contain all the numerical data. These tables are in press and will appear in 1919. * * *"

The following table [abridged] indicates the number of observations of each element:

	December.	January.	February.
Currents	22,021	20,762	18,657
Wind	116,082	105,652	95,965
Atmospheric pressure	105,867	95,043	87,097
Temperature of the air	108,164	97,560	89,392
Temperature of water	106,417	95,564	86,595
Cloudiness	113,955	102,876	94,794

Of the total number of observations of currents, 7,020 and 3,441, or 11.4 per cent and 5.6 per cent, were respectively, furnished by the Germans and the English; in addition, 7,020 observations of the wind, or 2.2 per cent of the total, were furnished by the Deutsche Seewarte.

Valuable navigational information has been added on the reverse of the charts by the assistant director, M. P. H. Gallé, who, in collaboration with the director, Dr. J. P. van der Stok, has directed the work.

There are eight charts for each month, as follows:

1. Currents, by 5-degree squares the frequency and mean velocity of surface water movement in each of 16 directions.
2. Winds, same as for currents, except that only eight directions are covered.
3. Currents, general circulation of the surface water, by 2-degree squares the resultant frequency and mean velocity to the nearest one of the 32 points of the compass.
4. General circulation of the air, same as for the currents.

[1] Oceanographische en meteorologische waarnemingen in den Atlantischen Ocean December, Januari, Februari 1870–1914. Kaarten. Koninklijk Nederlandsch Meteorologisch Instituut No. 110. 24 plates. 44½ x 51 cm.

[2] Cf. MONTHLY WEATHER REVIEW, Nov., 1918, 46: 510–512.

[3] Translated from the French by E. W. Woolard.

5. Mean sea-level pressures, by 2-degree squares, to the nearest tenth of a millimeter. Isobars for every 2.5 millimeters.

6. Air temperatures, by 2-degree squares to the nearest tenth of a degree centigrade. Isotherms for every 5 degrees centigrade.

7. Ocean surface temperatures, same as for air temperatures.

8. Routes, trajectories of cyclones, limits of fog, ice, the trades and the monsoons (with a page of discussion in Dutch). In connection with discussions in Dutch there are additional charts in the text showing the frequency of fog in the northwestern North Atlantic, a storm weather map of the North Atlantic, and the frequency of gales in the Atlantic.—*C. F. B.*

NOTES, ABSTRACTS, AND REVIEWS.

RETIREMENT OF MR. HENRY E. WILLIAMS.

Mr. Henry E. Williams, some time Chief of the Forecast Division, was among the first employees of the United States Weather Bureau on duty in Washington, D. C., to be placed on the retired list, August 20, 1920.

Mr. Williams is a veteran of the Civil War, having had three years service as first sergeant in the 17th Connecticut Volunteers. Shortly after the close of the war he enlisted in the Regular Army. He received his discharge in 1876, and immediately enlisted in the United States Army Signal Corps. His combined military and civil service aggregates 52 years and 4 months, 44 of which were spent in the Weather Service.

The greater portion of Mr. Williams's tour of duty in the meteorological service was spent in the Forecast Division of the central office in Washington. While not himself a forecaster, being chiefly concerned with administrative matters in connection with the division, he had the unique experience of a close-up view of the forecasting activities of the Army Signal Corps and the civilian organization—the United States Weather Bureau—that succeeded it in 1891.

He was assistant chief of the Weather Bureau from July 1, 1903 to June 30, 1912. The position in which he was best known to the men of the service was however that of assistant instructor at Fort Myer, Va., during the eighties. It was his custom in making the daily trip between Georgetown and Fort Myer to ride a fine old gray mule. In the minds of those who attended the school, the recollection of Instructor Williams astride the gray mule continues to be one of the most highly cherished landmarks of the time.

Mr. Williams is one of the best known and highly esteemed men of the Weather Service. His associates unite in congratulating him upon rounding out more than a half century of useful service to his country.—*A. J. Henry.*

Dr. Jesse C. Green, 1817-1920.

Dr. Jesse C. Green, cooperative observer at West Chester, Pa., died on July 26, 1920, at the age of 103 years. His death was caused by an accident, a fall from a step ladder.

Dr. Green began keeping weather records at West Chester in January, 1855, and continued without interruption until the time of the accident that caused his death. It is believed that this individual record for more than 66 years is unparalleled in this country, if not in the world.

It was a cherished desire of Dr. Green's that the Weather Bureau should publish his records as a separate pamphlet, and they were compiled for that purpose, but unfortunately the available funds would not permit of the expense, and his hopes were never realized.—*George S. Bliss.*

DR. G. C. SIMPSON BECOMES DIRECTOR OF THE BRITISH METEOROLOGICAL OFFICE.

[Reprinted from Science, London, August 5, 1920, p. 721.]

Dr. G. C. Simpson, F. R. S., Meteorologist to the Government of India, has been appointed Director of the Meteorological Office as successor to Sir Napier Shaw, who retires on reaching the age limit after brilliant pioneer service. Dr. Simpson was meteorologist and physicist to the British Antarctic Expedition, 1900-1913, and served on the Indian Munitions Board from 1917 to 1919. In 1905 he was appointed a Scientific Assistant in the Meteorological Office, and in 1906 joined the staff of the Indian Meteorological Department. He is the author of a number of papers of scientific importance, including one on the electricity of rain and its origin in thunderstorms, published in the Philosophical Transactions in 1909. Only last year Dr. Simpson completed an elaborate discussion of the meteorological work of the British Antarctic Expedition, 1910-1913. As successor to Sir Napier Shaw his appointment promises a continuation of progress along lines which will advance meteorological science and maintain the high position which the British Meteorological Office now occupies through its work in recent years.

COOPERATION IN THE INVESTIGATION OF GEOPHYSICAL PROBLEMS IN HIGH LATITUDES.

[Reprinted from The Meteorological Magazine, London, July, 1920, vol. 55, pp. 121-122.]

The recent visit of Captain Roald Amundsen to Berings Strait has again directed general attention to his projected voyage across the Polar Sea. In spite of the difficulties of organizing international cooperation at the present time, it is hoped that a large number of stations will be provided at various points in high latitudes so that observations of meteorological and magnetic phenomena, and especially of the aurora borealis, may be available for comparison with those of Amundsen's party. The Meteorological Office is organizing an observing station in the Shetland Islands for the purpose.

A publication entitled "Various Papers on the Projected Cooperation with Roald Amundsen's North Polar Expedition" has been circulated from Christiania by the Norwegian Geophysical Commission. It contains memoirs on the importance of various parts of the work, and also practical suggestions with regard to apparatus and methods. The authors are Th. Hesselberg, O. Krogness, and Carl Størmer.

Of special interest in connection with the projected observations is the memoir by L. Vegard and O. Krogness on "The Position in Space of the Aurora Polaris," issued by the same Commission. The memoir is illustrated by no less than 434 pairs of photographs from which the height of the aurora has been determined on as many occasions. Even on the small scale of the reproductions

the corresponding points on the photographs taken with cameras about 30 km. apart can generally be recognized. An interesting novelty is the successful use of the kinematograph for auroral photography. As to the results set out in the memoir, the most important appears to be a confirmation of the discovery that the lower limit of the draperies tends to fall at one or other of two somewhat closely defined levels, 100 and 107 km. above sea level, a discovery which must, in the opinion of the authors, almost inevitably lead to the conclusion that a predominant part of the cosmic rays coming from the sun and producing the aurora borealis is made up of two groups of rays, each of which has its own quite definite penetrating power.

The development of auroral photography in the Shetlands, the most promising region of the British Isles for the purpose, will be awaited with great interest.

OCCURRENCE OF OZONE IN THE ATMOSPHERE.

[The Victoria University of Manchester, July 14, 1920.]
[Reprinted from Nature, London, July 22, 1920, p. 645.]

With reference to the lecture of Lord Rayleigh published in *Nature* of July 8 on "The Blue Sky and the Optical Properties of Air," the conflicting results obtained by chemical methods in the estimation of atmospheric ozone are recalled. I beg to direct attention to my paper on "The Occurrence of Ozone in the Upper Atmosphere" (Proc. Roy. Soc., 1914, A, vol. xc, p. 204), in which it is shown that a reagent of potassium iodine solution can be made to provide a basis for the distinction of ozone and oxides of nitrogen at high dilutions and enable the approximate estimation of the former. By this method it is shown that, in accordance with the conclusions of Lord Rayleigh, ozone is present in the upper atmosphere, the amount present at an altitude of 10,000 feet being *of the order of* 5×10^{-6} parts per unit volume. Measurements made with sounding balloons up to altitudes of 20 km. also showed the presence of definite amounts of ozone, but no detectable increase between 4 km. and 20 km. The view was put forward that this amount of ozone must be taken into account in considering the optical properties of the sky.

An extension of these measurements was made with greater precision at the Mosso Laboratory on Monte Rosa at an altitude of 15,000 feet, where an average proportion of about 1×10^{-6} parts per volume of ozone was found.—*J. N. Pring.*

THE RELATIONSHIP BETWEEN CLOUD AND SUNSHINE.[1]

By J. R. Sutton.

[Abstract reprinted from Nature, London, July 22, 1920, p. 667.]

A brief discussion of the observations of sunshine and cloud made during the 20 years, 1900–1919, at Kimberley. In a general way much sunshine postulates little cloud; but the relation is not intimate, and a sunshine recorder can not be regarded as an automatic device for determining the cloudiness of the sky. August gets the most sunshine and February the most cloud.

ATMOSPHERIC AND TERRESTRIAL RADIATION.

By W. H. Dines.

[Abstracted from Quar. Jour. Roy. Meteorological Soc., 46, 163-173, April, 1920.]

The atmosphere is divided into 10 layers of equal mass, each thus contributing 100 mb. to the pressure near sea level. The radiation emitted by each layer on each side is assumed to be $\eta\sigma T^4$, where T is the absolute temperature, σ Stefan's constant, and η a constant depending upon the humidity, mass, cloudiness, etc., of the layer. The proportion of incident radiation absorbed by a layer is η, $1-\eta$, being transmitted. Then the net radiation absorbed or omitted by any layer as a consequence of the absorption and emission by the earth and the rest of the atmosphere may be calculated. For thirteen widely different assumptions as the values of η and their distribution, corresponding to different vertical distributions of cloudiness, etc., the same general results were obtained: The known mean values of T over England show that all strata up to the 400 mb. level are emitting more radiation than they are abosrbing, those from 400 mb. to 200 mb. are absorbing more than they emit, and those above 200 mb. are again suffering a net loss. Since the mean temperatures are not undergoing a systematic change, the losses and gains must be compensated for. In the lower layers the loss is made up by heating due to latent heat of condensation and to *solar* radiation, mainly through contact with the ground and convection; in the highest layers, probably by direct absorption of solar radiation. The gain in the intermediate layers is balanced by the loss due to forced mixing of different layers by winds, resulting in a tendency to estsblish an adiabatic lapse rate where normally the lapse rate is considerably less than adiabatic.

Equatorial temperature distributions, on the other hand, show that all the strata above 400 mb. are gaining by absorption, probably because of the small amount of emission at the low temperatures existing there. This indicates that these low temperatures are due to dynamic, not to radiational, causes.

This method of computation, devised by L. F. Richardson as a substitute for the complex methods used by Gold in his studies on the stratosphere, gives a value for the total loss of heat by the earth in good agreement with that of Abbot and Fowle.—*E. W. W.*

LONG-RANGE FORECASTING IN JAVA.

By C. Braak.

[Reprinted from Nature, London, August 5, 1920, pp. 729-730.]

Publication No. 5, 1919, of the Royal Observatory of Batavia, entitled "Atmospheric variations of short and long duration in the Malay Archipelago and neighboring regions, and the possibility to forecast them," by Dr. C. Braak, embodies the results of a long investigation into the sequence of rainfall in the equatorial regions east of the Indian Ocean. Three kinds of variation are studied: (1) With periods of one or more years up to and including the sun-spot period; (2) secular variations; and (3) with periods less than a month, comparable with Abbot's short-period solar fluctuations. The variations, the period of which is intermediate between (1) and (3) above, are treated as disturbances of (1). Dr. Braak lays much stress on a three-year period, of the persistence of which he gives plausible, though not quite convincing, examples. He classifies three groups of years, of high barometer, low barometer, and transition (from high to low), but naturally finds a proportion of years not strictly true to any of these types. It is scarcely surprising that he finds in general a correlation between barometric pressure and rainfall. For the east monsoon he finds strong positive correlation between high pressure and drought, and weaker between low pressure and excess of rain. For the west monsoon he finds, with

[1] Royal Society of South Africa, Cape Town, May 19.

local exceptions, excess of rain with high barometer, and deficit with low barometer. His problem is thus reduced to the intensity of the correlation and the chances of a correct forecast of the barometer variation. His next step takes into account temperature changes which may be expected to modify pressure conditions, but his result is disappointing. He obtains rules, but their application is so far a failure that they appear to break down most thoroughly in years of drought—that is, when, if correct, they would be most valuable.

Turning to secular variations, he finds no evidence of progressive change in Batavian rainfall; in fact, the only progressive change on which he lays stress is in Batavian air temperature. Comparison with stations in India, Australia and other places in the same quarter of the globe provides other types of change, but none agreeing with Batavia, and the question is left unsolved.

There remain the short-period pressure waves. The equatorial manifestations of these he attributes to a kind of surge, caused by the great disturbances in higher latitudes, exercising a sucking influence or its converse, with slight variations of the rainfall, less than 10 per cent of the normal, the effect of which is to compensate the pressure difference by cooling or heating air probably above the 3,000-meter level.

Other variations of rainfall, humidity, and cloudiness he considers to be local, and, on the whole, rejects the possibility of forecasting any short-period variations in the rainfall. Inasmuch as we are bound to regard the Tropics as the first stage in the translation of solar variation into weather, it seems a pity that the result obtained in what is probably the best-known region of the Tropics in regard to meteorological statistics should appear so meager and wanting in definiteness.[1] Similar work in temperate regions may well be discouraged, but there is still an enormous mass of data.—*W. W. B.*

PROBABLE AMOUNT OF MONSOON RAINFALL IN 1920.

By GILBERT T. WALKER.

[Reprinted from Nature, London, August 5, 1920, pp. 724-725.]

A memorandum regarding the probable amount of monsoon rainfall in 1920, by Gilbert T. Walker, has recently been issued. Data of importance are given, showing how the monsoon rainfall in India is affected by previous weather conditions over various parts of the earth. In summing up the effects of the various factors it is mentioned that the prejudicial effect of snowfall from Persia to the Himalayas is exerted when at the beginning of June the accumulations extend over a larger area than usual. The great excess of snow reported this year is confirmed by the low temperatures in the Punjab. Heavy rainfall in South Ceylon, Zanzibar, East Africa, and Seychelles is prejudicial, but data for this year show a moderate deficit or normal conditions. A close relationship exists between heavy rain in Java from October to March and low barometric pressure in Bombay in the succeeding six months; in Java the rainfall was nearly normal and its effect is negligible. High barometric pressure in Argentina and Chile is a favorable condition, but this year pressure is in slight defect. It is stated that the conditions indicate in northwest India the monsoon is likely to be weak, at any rate in the earlier part of the season, and for the rainfall of the peninsula, northeast India, and Burma the indications are not sufficiently definite to justify a forecast.

[1] Cf. "Forecasting the weather on short-period solar variations," Monthly Weather Review, Mar., 1920, 48: 149-150, in which C. F. Marvin throws grave doubts on the reality of appreciable short-period solar variations. Therefore, this result does not seem anomalous.—EDITOR.

EFFECT OF THE RELATIVE LENGTH OF DAY AND NIGHT AND OTHER FACTORS OF THE ENVIRONMENT ON GROWTH AND REPRODUCTION IN PLANTS.[1]

By W. W. GARNER and H. A. ALLARD.

[Abstract reprinted from Experiment Station Record, Dept. Agr., Washington, v. 42, no. 9, p. 818.]

The results are given of investigations carried on by the authors in the Bureau of Plant Industry, U. S. Department of Agriculture, in which a dark chamber was used for growing plants, by which the number of hours of exposure to sunlight could be controlled. As a part of the investigation, a series of plantings of soy beans was made in the field at intervals of three days throughout the season, in order that the effects produced by different dates of planting could be compared with those produced by artificial shortening of the daily exposure to light.

Tobacco, soy beans, and a large number of other plants were experimented with, and it was found that the relative length of the day was an important factor in the growth and development of the plants, particularly with respect to sexual reproduction. In some species it was found that the normal plant could attain flowering and fruiting stages only when the length of the day falls within certain limits. Consequently, these stages of development are ordinarily reached only in certain seasons of the year. In the absence of favorable length of day for bringing into expression the reproductive processes in certain species, vegetative development was said to continue more or less indefinitely, thus leading to the phenomenon of gigantism. On the other hand, under the influence of a suitable length of day, precocious flowering and fruiting may be induced. In this way certain varieties or species may act as early or late maturing, depending on the length of day to which they happen to be exposed. The species exposed to a length of day favorable to the growth and sexual reproduction have shown a tendency to assume an ever-blooming or ever-bearing type of development.

The relationship between annuals, biennials, and perennials was studied, and under artificial conditions it was found possible to change the nature of the plants materially. In all species studied the rate of growth was found directly proportional to the length of the daily exposure to light, but within the limits of the experiment light intensity was not found a factor of importance. With soy beans, limiting water, inducing temporarily wilting daily, was without effect on the date of flowering, although the drought hastened the final maturing of the seed. Interrelationships between length of day and prevailing temperatures of the winter season are said to control successful reproduction largely in many species and their ability to survive in certain regions. The authors point out that the relation between the length of the day and the time of flowering is of great importance in crop yields, and indicates the necessity for seeding at the proper time.

[1] Journ. Agr. Research, U. S. Dept. Agr., Washington, 18 (1920), No. 11, pp. 553-606, pls. 16, figs. 3.

TEMPERATURE IN RELATION TO QUALITY OF SWEET CORN.

NEIL E. STEVENS and C. H. HIGGINS, Journal of Agricultural Research, September 15, 1919, Volume XVII, No. 6.

This paper refers to the reputation of sweet corn grown near the northern limits of cultivation, for sweetness and quality, as compared with that canned in more southern districts, and states that this difference is not due to a difference in sugar content of the corn when it is picked, but because of the lower temperature at harvest time.

It shows that sweet corn deteriorates very rapidly after it is picked, and that the rate of deterioration depends upon the temperature. Tests developed the fact that at a temperature of 20° C. (68° F.) corn lost from one-fourth to one-third of its total sugar, during the first 24 hours after picking, or more than twice as much as that kept at a temperature of 10° C. (50° F.). Also that kept at a temperature of 30° C. (86° F.) more than 50 per cent of the sugar was lost during the same period. The respiration is very high during the first day after corn is pulled from the stalk, and the rate increases with higher temperatures. "With corn at a temperature of 25° C. (picked near noon on a warm day) there was over 19 per cent carbon dioxide at the end of 4 hours. With corn at a temperature of 15° C. (picked in the morning) 8 hours were required to reach practically the same point, while with still cooler corn the point was not passed in 10 hours." In this connection it is pointed out that corn which had been kept for some time in an atmosphere deficient in oxygen was of extremely poor quality.

The authors called attention to the fact that the corn-picking season in Maryland is in August, when the daily average temperature (at Baltimore) is about 75° F., while the picking season in Maine is in September, when the average daily temperature (at Portland) is about 60°. Thus the deterioration of corn during a given period after picking would be much greater, in an ordinary packing season under the higher temperatures that prevail in Maryland than with the considerably cooler weather that obtains in Maine at harvest time.—*J. Warren Smith.*

CLIMATE AND WEATHER AND PLANT DISEASES.

The following extracted from the Plant Disease Bulletin Supplement No. 9, Bureau of Plant Industry, United States Department of Agriculture, shows the distribution of some plant diseases under the influence of climate, and the development as affected by different weather conditions:

"Apple Scab caused by *Venturia inaequalis* (Cke.) wint.—Favored by early and continued rains together with cool temperatures which prevailed over most of the eastern and central apple growing regions for about one month after the blooming period, apple scab, in 1919, appeared in many states with unprecedented severity and resulted in enormous losses.

"The main reason for this great outbreak of apple scab can be directly attributable to the unusual weather conditions in late April and during the month of May. The accumulation of scab during previous years was evidently a factor, but there was altogether too much rainy, cloudy, and damp weather during an entire month, beginning about the time the apple trees came into bloom. For example, the official Weather Bureau meteorological records at Washington, D. C., beginning April 24 and ending May 24, show only three periods with clear weather—one clear day, April 24; two clear days, May 2 and 3; and two clear days May 18 and 19. During this period of 31 days, there were rains on 21 days, counting those in which a trace is recorded, and a trace is probably as effective on cloudy days as a heavier rain, not to mention the heavy dews with which the fruit and foliage were saturated on other cloudy days. Of the 21 days with rain, only 6 were marked 'partly cloudy,' which means that the sun shone through the clouds part of the time. The other 15 days were cloudy all day. Of the 10 days in which no rain fell, 5 only have already been accounted for as clear. Of the remaining 5 days, two were cloudy and 3 were partly cloudy.

"It is evident that there was almost a continuous infection period for 31 days, beginning when the apple trees were in bloom in the middle portion of this region, slightly preceding bloom in the northern sections, but following closely after bloom in the southern sections, and in general, occurring at the most dangerous period from the standpoint of apple scab. This is plainly the most important factor in the outbreak."

"Bitter rot caused by *Glomerella cingulata* (Stonem) S. & S.—Bitter rot is typically a disease of humid hot sections, extreme heat being especially favorable for its development. Those sections in which there are periods of extreme heat without appreciable temperature diminution at night with occasional showers or rainy periods are especially well situated for the development of bitter rot."—*J. W. Roberts.*

"Blotch caused by *Phyllosticta solitaria* E. & E.—Apple blotch, so far as known, occurs only in the Central and Southern States of the eastern half of the country. It has apparently not advanced beyond the northern borders of New Jersey, Pennsylvania, Ohio, Indiana, Illinois, and Iowa. One case was reported from a nursery in Wabasha County, Minn., in 1917, on imported nursery stock, but it is understood to have been eradicated. It is reported from a few localities in South Dakota, and is abundant in Nebraska, Kansas, Oklahoma, and Texas, but is not known to occur farther west."

"Rust caused by *Gymnosporangium juniperi-virginianae* Schw.—Apple rust is distributed over the Atlantic States from Maine to Georgia and extends westward as far as the outer boundaries of the nonirrigated apple belt. Extensive commercial production over this half of the country ceases at about the line of 18 inches annual precipitation, but rust is reported from scattered plantings practically up to the 100th meridian. It is not found in the irrigated districts, nor in the humid regions of the Pacific coast.

"In addition to the increase in the amount of infection, the unusual weather conditions of last spring, the excessive number of rainy and cloudy days occurring last spring, are undoubtedly an important factor in this outbreak."

"Black rot caused by *Physalospora cydoniae* Arnaud (*Sphaeropsis malorum* (Berk.). Pk.).—Black rot was reported by collaborators in 1919 from practically all apple growing regions in the eastern half of the United States, and also from Colorado and New Mexico. Greatest loss from this disease occurred in the States which lie east of the Mississippi and south of the Ohio and Potomac Rivers."

"Fire blight caused by *Bacillus amylovorous* (Burr.) Trevisan.—Fire blight occurred in 1919 in practically all States where the apple and pear are grown, but for the most part is perhaps the lightest infection of recent years. The group of States lying south of the Ohio and east of

the Mississippi, excepting Virginia and West Virginia, constitutes the only area reporting very severe losses to the apple crop from the disease in 1919."

"* * * This year in general there has been less pear blight in humid eastern United States than probably at any time previous to 1912. * * *"

"Powdery mildew caused by *Podosphæra leucotricha* (E. & E.) Salm.—Apple powdery mildew occurs from coast to coast and from the northern to the southern boundaries of the apple belt."

"In the irrigated districts the fungus depends upon the prevalence of dews for moisture for spore germination. First appearance of the disease is generally correlated with condition of full bloom, since infected buds that harbor the overwintering mycelium are delayed in opening until about this time."

"Sooty blotch caused by *Leptothyrium pomi* (Mont. & Fr.) Sacc.—Sooty blotch is widely distributed over the eastern half of the United States, or east of the 100th meridian. In 1919 Kansas reported 'Sooty blotch probably aided by wet season, very unusual for it to occur in Kansas.'"

"Drought spot (nonparasitic).—The term drought spot is used to refer to masses of dry corky tissue in the flesh of the apple. This trouble has been reported from various sections of Idaho where apples have been grown without irrigation and with insufficient moisture."

"Peach brown rot caused by *Sclerotinia cinerea* (Bon.) Schröt.—Brown rot was very prevalent in most of the peach States in the eastern half of the country during 1919. It was reported from all States where peaches are grown east of the 100th meridian and was present to some extent up and down the Pacific coast. (This disease affected plums and cherries over the same area.) Warm, moist weather is favorable for brown rot. Although collaborators did not report much about weather conditions, it is known that the wet weather at blossoming time in the Middle Atlantic States induced blossom blight in that section, and that the frequent summer rains favored the development of fruit rot in all the Eastern and Southeastern States."

"Scab caused by *Cladosporium carpophilum* Thüm.—Scab was reported from practically all peach States east of the one-hundredth meridian. It was common and widespread in most of these States and seemed to be of most importance in those in the South and East."

"Grape black rot caused by *Guignardia bidwellii* (Ellis) V. & R.—This, the most serious disease of the grape, occurred widely over the entire eastern portion of the United States. It was most serious in the southern two-thirds of the country, where warm weather prevailed and where spraying is not generally practiced, and also along the Atlantic coast, where the disease was favored further by abundant moisture."

The following from Bulletin No. 1, volume IV, dated July 15, 1920, indicate some effects of weather on plant disease in 1920:

"Wheat scab caused by *Gibberella saubinettii*.—Reports from some of the Eastern States, where wheat scab has been bad in certain other years, show that in those States the disease was much less prevalent on winter wheat than last year. This was probably on account of dry weather at heading time."

"Stem rust caused by *Puccinia graminis*.—If it should be warm and damp the spread will be rapid and early enough to be very destructive [North Dakota, July 8]."

"In Illinois (Anderson, May 21) apple scab appeared in the orchards about Urbana on May 16. This is quite late, but we have had very unusual weather this spring and it has been even too cold and rainy for apple scab."

"In Ohio black rot was developed noticeably in 1919 upon both twigs and fruit of apple following lime sulphur spray. The canker development upon twigs and branches is very prevalent. From present indications the cool moist weather conditions are leading to extensive infection of fruit and new growths."

"Peach leaf curl caused by *Exoascus deformans*.—Leaf curl was especially abundant this spring in some of the Middle Atlantic and Ohio Valley States. A cool, wet spring during bud opening doubtless favored the disease and also in some cases made it difficult to apply the dormant spray on time. In Illinois cold, rainy period throughout State this spring was probably the cause of unusual outbreak."

"Brown rot caused by *Sclerotinia cinerea*.—In Georgia, brown rot is present wherever fruit is not sprayed, but the dry weather appears to be holding it in check."

"Strawberry gray mold rot caused by *Botrytis* sp.—Gray mold rot is reported from Massachusetts, Connecticut, New Jersey, Ohio, Indiana, Illinois, Michigan (occasionally in Ingham County, no loss), Alabama (at Auburn), Louisiana, Texas, and California. Wet weather favored its development in Massachusetts, Ohio, and California."

"I am inclined to attribute this superabundance of Botrytis [in southern California strawberries, Jan.–Mar.] to the very large proportion of cold weather—that is, weather too cold for most fungi but fairly favorable to Botrytis. I am now at work on curves of hourly temperatures, and it is evident that during these months a large number of hours show temperatures of the kind mentioned. This or some other favorable conditions make Botrytis very common during even very dry weather."—*J. Warren Smith.*

BIBLIOGRAPHY.

RECENT ADDITIONS TO THE WEATHER BUREAU LIBRARY.

C. FITZHUGH TALMAN, Professor in Charge of Library.

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

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Klimaschwankungen 1813 bis 1912 in Vorderindien. Stuttgart. 1918. p. 212-256. (Sonderdruck. Bibliothek geographischer Handbücher. Festband Albrecht Penck.)

Eckersley, T. L.
Observations of solar radiation. Cairo. [1914] p. 114-126. 27½ cm. (Survey dept., Egypt. Helwan observ. Bull. no. 14.)

Gorczyński, Władysław.
Niektóre wiadomości o pradach atmosferycznych oraz o ich zwiazku z klimatami na kuli ziemskiej. (Wedug W. Köppena, A. Hettnera, R. Süringa, H. Hildebranssona, i Teisserenc de Borta.) Warsaw. 1919. 46 p. 25 cm.

Nowe izotermy Polski, Europy, i kuli ziemskiej, z dodatkiem o charakterze klimatycznym Polski. (Nouvelles isothermes de la Pologne, de l'Europe et du globe terrestre,) Warsaw. 1918. 286 p. 37 figs. 48 charts. 30 cm. [Text in Polish; résumé in French.] [Abstract in this REVIEW, p. 411.]

O Ciśnieniu Powietrza w Polsce i w Europie. (Pression Atmosphérique en Pologne et en Europe.) Warsaw, 1917. 265 p. 14 figs. 54 charts. 30 cm. [Text in Polish; résumé in French.] [Abstract in this REVIEW, p. 412.]

O wyznaczaniu stopnia kontynentalizmu wedug amplitud temperatury. (Méthode de calculer le degré du continentalisme en fonction de la température.) Warsaw. 1918. p. 500-547. 25 cm. (Extrait des Comptes rendus de la Société des sciences de Varsovie. 1918. XI Année. Fasc. 4.) [Text in Polish; résumé in French.]

O zmianach okresowych w ciągu doby i o obserwacyach dugoletnicc ciśnienia powietrza w Polsce. (Variation diurne de la pression atmosphérique et quelques longues séries d'observations barométriques en Pologne.) Warsaw. 1916. p. 365-403. 25 cm. (Comptes rendus de la Société des sciences de Varsovie. 1916. IX Année. Fasc. 4.) [Text in Polish; résumé in French.]

Knoche, Walter.
"Valor de desecación" como factor climatológico. Santiago de Chile. 1919. 91 p. 26½ cm. (Trabajo publicado en los nos. 34 y 35 de la Revista Chilena de historia y geografia.)

Lloyd, Francis E.
Environmental changes and their effect upon boll-shedding in cotton. New York. 1920. 131 p. 25 cm. (Annals of the New York academy of sciences, vol. 29.)

Moreux, Abbé Th.
Comment prévoir le temps. Paris. 1919. 269 p. 21½ cm.

Pogorzelski, Witold.
O teoryi pradow prostoliniowych w atmosferze. (Théorie des courants rectilignes dans atmosphère.) Warsaw. 1917. p. 282-322. 25 cm. (Extrait des Comptes rendus de la Société des sciences de Varsovie. 1917. X Année. Fasc. 3.) [Text in Polish; résumé in French.]

Rondeleux, M.
Cyclones. Théorie succincte, prévision et manoeuvre préventive d'après les trauvaux météorologiques récents. Manuel à l'usage des navigateurs. Paris. 1916. 80 p. 25 cm. (Extrait des Annales hydrographiques, 1916.)

Shaw, H. Knox.
Solar radiation during 1914. Cairo. 1915. p. 149-167. 27½ cm. (Ministry of public works, Egypt. Physical service. Helwan observatory. Bull. no. 17.)

Somigliana, C., & Vercelli, F.
Previsione matematica della temperatura nei grandi trafori alpini. Torino. 1912. p. 327-377. 33 cm. (Estr. dalle Memorie della R. Accademia delle scienze di Torino, serie 2, tom. 63.)

U. S. Air service.
Meteorology and aeronautics. Washington. 1920. 8 p. 28 cm. (Air service information circular, v. 1, no. 77.) [Abstract in later REVIEW.]

Zi-ka-wei observatory.
Atlas of the tracks of 620 typhoons 1893-1918, by Louis Froc, S. J., Director, Zi-ka-wei observatory. Zi-ka-wei (Chang-hai). 1920. 4 p. 23 charts. 31 cm.

RECENT PAPERS BEARING ON METEOROLOGY AND SEISMOLOGY.

C. F. TALMAN, Professor in Charge of Library.

The following titles have been selected from the contents of the periodicals and serials recently received in the Library of the Weather Bureau. The titles selected are of papers and other communications bearing on meteorology and cognate branches of science. This is not a complete index of all the journals from which it has been compiled. It shows on the articles that appear to the compiler likely to be of particular interest in connection with the work of the Weather Bureau.

Great Britain. Meteorological office. Monthly meteorological charts of the North Atlantic ocean. London. August, 1920.
Durst, C. S. The upper air and its relation to wind at the surface of the globe.

Meteorological magazine. London. v. 55. July, 1920.
Dines, W[illiam] H[enry]. The tilting rain gauge: a new autographic instrument. p. 112-113.
Locke, A. S. Temperature and "scent" [in hunting]. p. 117. [Dogs can follow a scent easily when the ground is warmer than the air, but only with difficulty when the ground is colder.]

Nature. London. v. 105. July 22, 1920.
Van Everdingen, E. Aerial navigation and meteorology. p. 637-638. [Criticizes Annexe G. of the Convention for the regulation of aerial navigation.]
Hobbs, Wm. H. The mechanics of the glacial anticyclone illustrated by experiment. p. 644-645. [A cooled dome in streakily colored water, or under a small source of smoke in air.]

Royal astronomical society. Monthly notices. London. v. 79. April, 1919.
Turner, H. H. On the fifteen-month periodicity in earthquake phenomena. p. 461-466.

Royal meteorological society. Quarterly journal. v. 46. July, 1920.
Douglas, C. K. M. Clouds as seen from an aeroplane. p. 233-242. [Abstract in later REVIEW.]
Description of the night sky recorder, recently brought into use at the Royal observatory, Greenwich. p. 243-244.
Silvester, N. L. Local weather conditions at Mullion, Cornwall. p. 245-270.
Clark, J. Edmund. The Surrey hailstorm of July 16, 1918. p. 271-288.
Brooks, C. E. P. Distribution of relative humidity over Nigeria. p. 289-292. [Abstract in later REVIEW.]
Richardson, L. F. Sun-flash balloons for continuous signalling. p. 293-294.
Rambaut, A. A. Meteorological work at the Radcliffe observatory, Oxford, 1919. p. 311-312.
Mr. T. W. Backhouse, F. R. A. S. p. 312-313. [Obituary.]
Ward, Robert De C[ourcy]. Mr. Maxwell Hall, M. A., F. R. A. S. [Obituary.] p. 313-314.

Scientific American. New York. v. 123. Aug. 21, 1920.
Whiting, Wendell M. Record weather. Excessive precipitation, temperature extremes, high winds, blizzards, hurricanes, and tornadoes. p. 190-191.

Archives des sciences physiques et naturelles. Genève. 123 année. Mai juin, 1920.
Gruner, P[aul]. La formation de rayons dans la lumière pourprée. p. 247-248.
Borel, Ch[arles], & Jaquerod, A. Sur un constituant inconnu de l'air atmosphérique. p. 265. [Laboratory experiments to determine whether an unknown light gas exists in the atmosphere. Results negative.]

France. Académie des sciences. Comptes rendus. Paris. Tome 171. 12 juillet 1920.
Zeil, G. Sur la constante proportionnelle reliant la fréquence sismique à la fréquence des chutes pluviales. p. 117-119. [Abstract in June REVIEW, p. 356.]

Nature. Paris. 48 année. 17 juillet 1920.

Weiss, E. L'utilisation du vent comme force motrice. p. 39–43.

Meteorologische Zeitschrift. Braunschweig. Band 37. 1920.

Schmidt, Wilhelm. Über den täglichen Temperaturgang in den unteren Luftschichten. p. 49–59. (März/April.)

Pinkhof, M. Gockel, A.: Beiträge zur Halotheorie. p. 60–67. (März/April).

Nowotny, Friedrich. Meteorologische Betrachtungen anlässlich der Explosionskatastrophe in Kiew am 6. Juni 1918. (März/April.) Abstract in later REVIEW.

Schreiber, Paul. Zur polytropen Atmosphäre. p. 73–77. (März/April.)

Emden, R[obert]. Bemerkungen zu den Aufsatze von Fr. Linke über: Die Grundgleichungen der polytropen Atmosphären. (März/April.)

Dorno, C. Über den optischen Reinheitsgrad der Erdatmosphäre im Jahre 1919 und im Januar/Februar 1920. p. 79–82. (März/-April.)

Hann, J[ulius] v. W. v. Kesslitz, Die Meteorologie von Pola. p. 85–87. (März/April.)

Maurer, J[ulius]. Einige Resultate des Sonnenschein-Chronographen, verglichen mit dem Glaskugel-Heliographen. p. 88–89. (März/April.)

Sassenfeld, Max. Aus 25 jährigen Aufzeichnungen der Sonnenscheindauer in Hohenheim und Stuttgart. p. 89–91. (März/-April.)

Galbas, P. A. Vorläufige Mitteilung über Sichtbeobachtungen am Taunus-Observatorium. p. 91–92. (März/April.)

Meteorologische Zeitschrift. Brauenschweig. Band 37. 1920—Con.

Rosenthal, Elmar. Bemerkungen zu den Szintillationsbeobachtungen auf dem Sonnwendstein. p. 92–94. (März/April.)

Hann, J[ulius] v. Die aufsteigenden Bergwinde. p. 96–97. (März/April.)

Köppen, W[ladimir]. Die natürlichen Steinringe und Steinnetze der kalten Zone. p. 98–100. (März/April.)

Schmidt, Wilhelm. Über Ableitungen der ablenkenden Kraft der Erddrehung. p. 100–101. (März/April.)

Köppen, W[ladimir]. L. Satke, über den Zusammenhang der Temperatur aufeinander folgender Monate und Jahreszeiten. p. 102. (März/April.)

Range, Paul. Die tägliche Wärmeschwankung an der Oberfläche des Bodens im heissen ariden Klima. p. 102–104. (März/April.)

Exner, Felix M. Über die Polarisation des Lichtes in der Landschaft. p. 113–116. (Mai.)

Gockel, A. Über den Unterschied der Polarisation des Himmelslichtes in der Ebene und im Gebirge. p. 116–119. (Mai.)

Schreiber, Paul. Zur Wärmeleitung in der Atmosphäre. p. 119–126. (Mai.)

Dietzius, Robert. Die Beziehung zwischen dem Winde in der Höhe und dem bevorstehenden Niederschlage. p. 126–130. (Mai.) [Abstract in later REVIEW.]

Peppler, W[ilhelm]. Die Windverhältnisse der freien Atmosphäre. p. 135. (Mai.)

Schneider, Karl. Die Inversion an der Basis von Stratus mammatus. p. 137–139.

SPECIAL OBSERVATIONS.

SOLAR AND SKY RADIATION MEASUREMENTS DURING JULY, 1920.

By HERBERT H. KIMBALL, Meteorologist.

[Solar Radiation Investigations Section, Washington, August 30, 1920.]

For a description of instruments and exposures and an account of the method of obtaining and reducing the measurements the reader is referred to this Review for April, 1920, 48:225.

The monthly means and departures from normal in Table 1 indicate that solar radiation intensities were very close to normal at Washington, D. C., and Madison, Wis., and only slightly above at Lincoln, Nebr. At this latter station the afternoon intensities almost exactly equalled the morning intensities at corresponding air masses, which is unusual. But few measurements were obtained at Santa Fe on account of the absence of the observer from the station during a part of the month.

Table 2 shows an excess in the total radiation received on a horizontal surface at Washington and Madison during the four weeks, July 2 to July 29, inclusive, although at Madison there was a decided deficiency during the week, July 2 to July 8, inclusive.

Skylight polarization measurements obtained at Washington on five different days give a maximum of 57 per cent on the 27th, and a mean for the month of 51 per cent. These are average values for July at Washington. Measurements obtained at Madison on eight days give a maximum of 69 per cent on the 2d and a mean of 55 per cent. The very low polarization of 19 per cent measured on the morning of July 15 brings the average below the normal for July at Madison.

TABLE 1.—*Solar radiation intensities during July, 1920.*

[Gram-calories per minute per square centimeter of normal surface]

WASHINGTON, D. C.

Date.	Sun's zenith distance. 8 a.m.	77.8°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	77.8°	Noon.
	75th meridian time.	Air mass. A. M.					P. M.				Local mean solar time.
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.
July 1	13.13					1.33	0.96				10.97
9	16.79				1.01	1.25					14.10
13	17.37				0.68						15.11
20	13.13				0.75						12.68
21	15.11				0.66						14.10
23	18.59				0.65						19.23
26	8.48		0.92	1.04	1.23	1.40					8.18
27	9.47		0.87	0.99	1.17	1.35					8.18
28	10.59			0.65	0.84	1.10					11.38
29	12.68				0.84	1.10	0.79	0.62			10.59
30	14.10				0.89						15.65
Means			**(0.90)**	**0.89**	**0.87**	**1.26**	**(0.88)**	**(0.62)**			
Departures			**+0.17**	**+0.05**	**−0.05**	**+0.03**	**−0.09**	**−0.15**			

MADISON, WIS.

Date.	8 a.m.	77.8°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	77.8°	Noon.
July 2	18.59			0.93	1.12	1.36	1.08				17.96
3	14.60		0.91	1.02	1.15	1.37					12.24
10	11.38					1.35					10.59
11	13.61		0.60	0.75							11.81
14	10.21						1.15				8.48
15	11.38				0.64	1.01					9.14
16	9.47				0.96	1.34					8.18
17	9.14		0.59	0.69							12.24
23	17.37						1.05				17.37
26	9.14		0.86	0.96	1.14						8.18
27	9.14		0.66	0.79	0.99						9.83
28	9.14		0.66	0.80	0.95		0.89				9.83
Means			**0.71**	**0.85**	**0.99**	**1.29**	**1.04**				
Departures			**−0.05**	**−0.03**	**−0.01**	**+0.04**	**+0.06**				

TABLE 1.—*Solar radiation intensities during July, 1920*—Continued.

LINCOLN, NEBR.

Date.	Sun's zenith distances. 8 a.m.	77.8°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	77.8°	Noon.
	75th meridian time.	Air mass. A. M.					P. M.				Local mean solar time.
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
	mm.	cal.	cal.	cal.	bal.	cal.	cal.	cal.	cal.	cal.	mm.
July 1	14.10						1.05	0.95	0.85	0.79	17.96
2	13.13			1.01	1.20	1.42	1.08	0.96	0.80		14.10
3	11.81				1.15	1.39	1.19	1.00	0.87		14.10
7	11.38					1.38	1.19	1.03	0.92		10.97
8	9.47		0.95	1.07	1.22	1.41	1.20	1.03	0.89		10.21
9	10.59							1.03			10.59
10	10.97			0.95	1.10	1.40					10.97
13	17.37		0.74	0.91	1.06	1.32	1.00	0.77	0.60		17.37
14	11.81						1.09	0.92	0.76		16.64
15	12.68		0.77	0.90	1.12			0.88	0.73		8.81
18	16.20			0.81	1.01	1.22		0.73	0.58		16.20
22	14.10					1.34	1.13	0.88			14.10
23	15.65			0.96	1.11		1.13	0.96	0.82		17.96
28	12.24		0.65	0.81	1.01	1.31	0.98	0.83	0.68		13.13
31	17.37					1.32					16.79
Means			**0.78**	**0.93**	**1.11**	**1.35**	**1.10**	**0.92**	**0.77**	**(0.79)**	
Departures			**−0.02**	**+0.03**	**+0.02**	**+0.01**	**+0.03**	**+0.03**	**+0.03**		

SANTA FE, N. MEX.

Date.	8 a.m.	77.8°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	77.8°	Noon.
July 28	8.18			1.11	1.26						9.83
Means				**(1.11)**	**(1.26)**						
Departures				**+0.03**	**+0.05**						

*Extrapolated.

TABLE 2.—*Solar and sky radiation received on a horizontal surface.*

[Gram calories per square centimeter.]

Week beginning—	Average daily radiation. Washington.	Average daily radiation. Madison.	Average daily departure for the week. Washington.	Average daily departure for the week. Madison.	Excess or deficiency since first of year. Washington.	Excess or deficiency since first of year. Madison.
	cal.	cal.	cal.	cal.	cal.	cal.
July 2	544	431	+30	−107	+1,014	−321
9	487	576	−15	+ 45	+ 910	− 7
16	530	555	+41	+ 35	+1,198	+239
23	517	569	+39	+ 72	+1,472	+746

MEASUREMENTS OF THE SOLAR CONSTANT OF RADIATION AT CALAMA, CHILE, JUNE, 1920.

By C. G. ABBOT, Assistant Secretary.

[Smithsonian Institution, Washington.]

NOTE.—The report for June, 1920, having been delayed in transmission, will be published in next issue of this REVIEW.—EDITOR.

WEATHER OF THE MONTH.

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

GENERAL PRESSURE CONDITIONS.

By H. C. FRANKENFIELD, Supervising Forecaster.

[Washington, D. C., Aug. 24, 1920.]

North Pacific Ocean.—At Midway Island there were several slight depressions, but, as a whole, the pressure averaged somewhat above the normal. At Honolulu pressure was generally low until July 20, and moderately high thereafter. The lowest pressure (29.84 inches), occurred on July 11.

Alaska.—Over the Aleutian Islands and northwest Alaska low pressure continued generally throughout the month, with lowest readings of 29.44 inches at Dutch Harbor on July 9, and of 29.26 inches at Nome on July 21. Over southern and northeastern Alaska pressure ruled high, with a principal crest from July 3 to 8, inclusive.

United States.—There was a period of low pressure during the early days of the month, and another lesser one over the northeastern quarter of the country and eastern Canada on July 24 and 25. Otherwise pressure averaged above normal.

North Atlantic Ocean.—Stations of observations at Bermuda and Horta. High pressure prevailed throughout the month, except for a few days over the eastern Atlantic.

NORTH AMERICA.

By H. C. FRANKENFIELD.

Neither cyclones nor anticyclones were of pronounced character. Pressure was above normal, as a rule, and, as stated in the general discussion, there were only two depressions that were worthy of mention. Temperatures were moderate over the eastern half of the country, but rather high, as a rule, over the western half.

Precipitation was abundant from the Atlantic States westward through the Plains States, decreasing gradually to little, or none, west of the Rocky Mountains, except along the north Pacific coast.

NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

The average pressure for the month was nearly normal or slightly above at land stations along the American Atlantic and Gulf coasts, as well as in the West Indies. In the Bermudas and the Azores there was a decided positive departure, while in the vicinity of the British Isles the pressure was slightly lower than usual.

According to reports received, the number of days on which gales were reported was somewhat below the normal, most of them occurring in the first and last decades of the month.

The number of days on which fog occurred was apparently not far from the normal on the Banks of Newfoundland, as well as over the eastern section of the steamer lanes and the American coast.

From July 1 to 11 the North Atlantic HIGH was unusually well developed, it being central during that period over the region between the Azores and Bermudas. No heavy winds were reported until the 5th, when a number of vessels between the 40th and 50th parallels and the 55th and 65th meridians encountered moderate southwesterly gales.

From the 1st to the 5th fog occurred over widely scattered sections of the steamer lanes, as well as along the American and European coasts, while from the 6th to the 8th it was confined for the most part to mid-ocean, with the exception that on the 8th it was observed at land stations in Nova Scotia and Scotland. By the 9th the fog area had spread over the Banks of Newfoundland, while from the 10th to the 22d the ocean was comparatively free, with the exception of the 20th, when it occurred in mid-ocean.

From the 6th to the 19th practically no gales reports were received, and the pressure was generally high over the greater part of the ocean south of the 50th parallel. On the 20th two vessels near the 40th parallel and between the 62d and 67th meridians encountered southwesterly gales, although high pressure still prevailed. From the 23d to the 26th conditions had changed but little, with high pressure, moderate winds, and not much fog.

On the 27th moderate southwest gales prevailed over a limited region between the 35th and 40th parallels and the 55th and 60th meridians. The observer on the British S. S. *Idaho* reports as follows: "At 7 a. m. fresh southwesterly wind; freshened into SSW. gale with high southwesterly sea. At 3.30 p. m. heavy rain squalls. Wind shifted to west and back to SSW., force 8. At 10.30 p. m. wind shifted to west. Rain squalls cleared and weather moderated."

On the 28th one vessel about 300 miles north of Bermuda reported a strong gale from the WSW., and the British S. S. *Rossano* in northern European waters reports as follows: "Gale began on the 28th. Lowest barometer 28.83 inches at 2 p. m. July 31. Position, 59° 05′ N., 13° 48′ W. End of gale on the 31st; highest force, 10; shifts of wind near time of lowest barometer reading, WSW-NW." This disturbance remained nearly stationary during the last three days of the month, as shown by Charts IX, X, and XI.

From the 24th to the 28th, and also on the 30th and 31st, little fog was reported, but on the 29th it occurred in the region between the 45th and 50th parallels and the 10th and 35th meridians.

NORTH PACIFIC OCEAN.

By F. G. TINGLEY.

The weather of July on the North Pacific Ocean is usually pleasant, and, on the whole, that for the July just past was no exception to the general rule. At the present writing 133 reports have been received covering various periods of the month and representing a total of 1,143 daily observations made on board vessels plying trans-Pacific routes. In all these reports gales were recorded on only 26 days, as follows: Force seven, 14 times; force eight, 3 times; force nine, 6 times; force ten, 1 time; force eleven, 2 times. Fog was observed on 116 days, which appears to be slightly under the average.

There appears to have been, however, rather more than the ordinary typhoon activity in Asiatic waters. The records for a period of 26 years (1893–1918) which have

recently been published by the Zi-ka-wei Observatory[1] show that during that period a total of 90 typhoons occurred in the month of July. Thus, some three or four of these tropical storms may be expected each year in this month. As nearly as can be judged from reports that have been received, four distinct typhoons occurred in July of this year. This statement is made, however, subject to modification by later reports.

The first of these storms appears to have reached the China coast at a point about midway between Hongkong and Shanghai on the 15th or 16th. The American steamship *Columbia*, Capt. Geo. Dockstader, from Hongkong for Shanghai, was under its influence during the 14th, 15th ,and 16th, though not near the center at any time. The *Columbia* left the former port at 4 p. m. on the 14th with a light SW. wind and falling barometer, the reading at that hour being 29.67 inches. The barometer continued to fall steadily, reaching 29.37 inches at midnight of the 15th, the wind, however, continuing light, WSW. During the early morning of the 16th the wind freshened and backed to SSW., force 6. Later, at 4 a. m., it increased to force 10, the barometer at that hour reading 29.20 inches, corrected. This was the lowest reading recorded. By 12 p. m. of the 16th the barometer had risen to 29.55 inches, though subsequently, during the early hours of the 17th, there was a further slight fall to 29.35 inches; this was at 4 a. m. The wind at that hour was ESE., force 5. At noon on the 17th the barometer read 29.64 inches, wind E., light, the *Columbia* at that time nearing Shanghai.

The British steamship *Tyndareus*, Capt. C. B. Francis, from Manila toward Kobe, via Hongkong and Keelung, was also under the influence of this storm during the 14th and 15th. On the 14th (noon position, G. M. T., latitude 27° 29′ N., longitude 123° 12′ E.) the *Tyndareus* experienced strong N. to NNE. winds with frequent hard squalls and a high, confused sea. The barometer at noon read 29.04 inches, corrected. These conditions continued through the 15th. The lowest barometer recorded was 28.96 inches at 4 p. m. of the 15th, local time, and the highest force of wind 11, from ESE.

[1] Atlas of the Tracks of 620 Typhoons, 1893-1918. Louis Froc, S. J., Shanghai, 1920. Reference to this valuable work will be made in a subsequent issue of the REVIEW.

Nothing is known as yet regarding the earlier history of this storm.

Information regarding three subsequent typhoons is only meager and is contained in a report received from the U. S. Army Transport *Great Northern*, Capt. L. R. M. Kerr, from San Francisco for Manila, via Honolulu. Capt. Kerr reports that from 5 a. m. of the 21st to 2 p. m. of the 24th the *Great Northern* was hove to at the south end of Paagan Island, Ladrone Group, waiting for three typhoons in the near vicinity to leave. The typhoons were as follows: One north of Guam, moving north; a second in or near the Balingtang Channel; and a third near Shanghai. It is assuned that Capt. Kerr received information respecting these typhoons by radio. Aside from the typhoons mentioned the only storm of consequence during the month appears to have been one that occurred near mid ocean on the 6th and 7th. The following report of this storm has been received from Mr. E. Turney, fourth officer and observer on the British R. M. S. *Empress of Asia*, Capt. A. J. Hailey, R. N. R., Vancouver for Yokohama.

On Tuesday, the 6th, at 7 a. m., the barometer commenced to fall fast, with a moderate wind and sea. This was in latitude 51° 30′ N., longitude 171° 9′ W. At noon the barometer was 30.02 inches with a fresh wind increasing. At 3 p. m., baromerer 29.71 inches, moderate gale. At 8 p. m., gale continuing, with heavy swell from the SW., rough sea and dense fog. At 9 p. m. gale began to moderate; dense fog continued. Midnight, barometer 29.09 inches, light wind, dense fog. At 2.10 a. m., 8th, ship meanwhile having crossed 180th Meridian wind shifted to NW. and fog cleared; barometer, 29.09 inches. Four a. m. barometer 29.07 inches, moderate wind, SSE. swell. At 5.30 a. m. barometer started to rise; ship's position, latitude 50° 20′ N., longitude 177° 58′ E. At 6 a. m., barometer 29.05 inches, strong wind. Noon, barometer 29.24 inches, strong WNW. wind. Four p. m., barometer 29.31 inches, strong wind.

Reports from 16 vessels on coastwise voyages show no unusual weather conditions.

Observers on several vessels report having seen shooting stars or meteors. The most important of these appears to have been one observed on board the American S. S. *Olen*, Capt. C. A. Darling, Kobe for Portland. Mr. Wm. Wallace Flynn, third officer and observer on the *Olen*, reports that on July 16, at 10.45 p. m., a brilliant meteor was seen lasting 9 seconds. Ship's position at 9.20 p. m., latitude 36° 21′ N., longitude 143° 15′ E.

NOTES ON WEATHER IN OTHER PARTS OF THE WORLD.

British Isles.—* * * The month was wet, cool, and cloudy, with a marked deficiency of sunshine. * * * The general rainfall expressed as a percentage of the average was: England and Wales, 161; Scotland, 104; Ireland, 153. * * *.[1]

Spain.—Madrid, July 27.—Latest reports from Barcelona indicate that the recent storm which swept northern and northwestern Spain caused damage estimated at millions of pesetas. Numbers of houses and stores collapsed and others were inundated as torrents of water rushed through the streets. Quantities of goods stored on the wharves, including large consignments of German dyes of great value, were washed to sea.—*Brooklyn Daily Eagle, July 28, 1920.*

Mediterranean Region.—In Italy and the eastern Mediterranean the weather throughout the month was fine and warm, temperatures frequently exceeding 90° F., while at Cairo on the 12th a temperature of 101° F. was reached.[1]

Iceland.—On the 27th a deep depression approached and remained in the vicinity of Iceland * * * [causing] a continuation of unsettled weather in Northwest Europe up to the end of the month.[1]

[1] The Meteorological Magazine, Aug., 1920, 154-155, 160.

Korea.—Honolulu, July 21.—Considerable property damage has been done by floods in the Seoul and Fusan districts of Korea, said Tokyo cables received to-day by Nipu Jiji, a Japanese language newspaper here.—*Chicago Evening Post, July 21, 1920.*

Philippine Islands.—Manila, July 26.—Thousands were rendered homeless by a typhoon which, accompanied by torrential rains, swept the Island of Luzon during the past ten days or two weeks, causing tremendous damage.

A dike of the Turlac River, Central Luzon, was broken, flooding thousands of acres of rice and sugar lands and carrying off hundreds of small houses. Loss of life was reported small.—*N. Y. American, July 27, 1920.*

India.—A message from Simla states that the monsoon in India continues to blow steadily.[1]

South Pacific Ocean.—Hit by the tail end of a terrific hurricane when three days out of Sydney and tossed about on a high sea for seventy-two hours, the Oceanic liner *Ventura* made port yesterday.

Five members of the crew were seriously injured when attempting to batten down one of the hatches, and the full list of 200 passengers were confined to their staterooms with seasickness during the fury of the storm.

The storm settled down about the vessel early in the evening of July 23. It came without warning and with severe fierceness, according to officers of the ship. (*San Francisco Examiner, August 11, 1920.*)

Argentina.—About the 14th of the month Buenos Ayres was visited by a snowstorm this being the second experienced within 300 years.[1]

Australia.—Floods in Australia have done much damage to wheatlands, and heavy rains, followed by destructive floods, have occurred in Western Queensland.[1]

[1] The Meteorological Magazine, Aug., 1920, 154–155, 160.

DETAILS OF THE WEATHER OF THE MONTH IN THE UNITED STATES.

CYCLONES AND ANTICYCLONES.

By R. HANSON WEIGHTMAN, Meteorologist.

Cyclones.—Alberta LOWS were the most frequent and there were few secondary developments. The table shows the number of LOWS by types.

LOWS.

	Alberta.	North Pacific.	South Pacific.	Northern Rocky Mt.	Colorado.	Texas.	East Gulf.	South Atlantic.	Central.	Total.
July, 1920	4.0	0.0	0.0	2.0	1.0	0.0	0.0	1.0	3.0	11.0
Average number, 1892-1912	4.8	0.7	0.3	0.5	0.9	0.2	0.1	0.1	0.9	8.6

Anticyclones.—The Alberta type was by far the greatest in number, as shown by the table which follows:

HIGHS.

	North Pacific.	South Pacific.	Alberta.	Plateau and Rocky Mountain region.	Hudson Bay.	Total.
July, 1920	1.0	1.0	6.0	0.0	1.0	9.0
Average number, 1892-1912	1.3	0.3	3.0	1.2	0.8	6.6

NOTE.—Since the inauguration of tables, giving the numbers of HIGHS and LOWS each month, in the January, 1920, number of the MONTHLY WEATHER REVIEW, it has been noted that the numbers of HIGHS and LOWS has exceeded in most cases the average for the period 1892-1912, and in a number of cases to a considerable extent. This seeming abnormality is, however, apparent rather than real, for in the greater part of the period for which the averages are computed, only the most important HIGHS and LOWS were plotted, whereas at the present time the policy is to track all HIGHS and LOWS that affected the weather to any considerable extent and this can be followed for 3 or more consecutive 12-hour periods on the weather map.

THE WEATHER ELEMENTS.

By P. C. DAY, Climatologist and Chief of Division.

[Weather Bureau, Washington, Sept. 1, 1920.]

PRESSURE AND WINDS.

The distribution of pressure over the United States and Canada during the month was according to the usual summer type, although the averages were above the normal for the month in all districts save over the eastern shores of the Great Lakes and along the St. Lawrence Valley where they were slightly below.

No storms of importance traversed extensive paths, but pressure was moderately low over eastern districts on the 3d and 4th, and a LOW that developed over the Plains region about the middle of the first decade had a fairly distinctive movement to the Great Lakes and St. Lawrence Valley during the following few days. Also on the 18th pressure was moderately low in the Lake region and during the following two days, overspread the more eastern districts.

The areas of high pressure were much better defined than the LOWS and entered the United States from the Canadian territories to eastward of the Rocky Mountains, instead of from the far northwestern part of the United States, as is frequently the case during the summer months.

The general circulation of the atmosphere exhibited the usual sluggish conditions common to the mid-summer period, and winds of high velocity were infrequent, save in connection with local thunderstorms. High pressure over the southeastern States favored southerly winds over nearly all districts from the Plateau region eastward to the Atlantic coast, except along the Canadian border from the Great Lakes to the Pacific where they were frequently from northerly or westerly points. Along the immediate Pacific coast they were in the main from some westerly quarter.

TEMPERATURE.

Low pressure over the Central Valleys and to the westward during the first week of the month induced southerly winds and high temperatures over most districts, but particularly between the Mississippi River and the Rocky Mountains where maximum temperatures frequently ranged from 90° to 100° or more. Some of the highest temperatures of the month were recorded during this period over the East Gulf and South Atlantic States. About the 8th, higher pressure advanced into the middle Plains and a change to somewhat lower temperatures occurred over most districts. As the high area moved eastward, there was a general but slow return to the summer type of low pressure over the interior districts with a corresponding rise in temperature to about the normal near the end of the second week.

By the middle of the month a change to higher pressure had again brought cooler weather into the Central Valleys, extending thence eastward during the few days immediately following. In the Northwest and far West the temperatures continued generally slightly above normal during most of the first half of the month, the highest readings occurring on the 7th and 8th over Arizona, New Mexico, Utah, and portions of adjoining States.

During the early part of the third decade the development of low pressure over the districts between the

Great Lakes and Rocky Mountains again favored high temperatures in the Central Valleys and the maxima of the month, ranging frequently from 95° to 100° or more, were recorded from the 21st to 24th over nearly all northern and central districts from the Rocky Mountains eastward, except over the extreme northeastern States where the highest temperatures were observed on the 12th and 13th.

Lower temperatures overspread the Great Lakes and surrounding districts on the 25th and the weather continued cool for the season over much of the country from the Rocky Mountains eastward during the following few days. By the end of the month, however, high pressure had gradually shifted to the southeastern districts and temperatures had risen to normal or above over all portions of the country save in the Dakotas and portions of adjoining States where cooler weather had again set in.

The average temperatures for the entire month were above normal in practically all districts from the Great Plains westward. In portions of Montana the daily temperatures were above normal the entire month and the monthly mean was the highest ever recorded in any month. The eastern half of the country had monthly means somewhat below normal over practically all portions.

Along the Atlantic coast from the Carolinas to southern New England the average temperatures were again below normal as has been the case during practically all the months of the present year. In fact at some points the average temperature for each month in that period has been below normal. This condition has probably been caused in part by the low temperature of the adjacent ocean waters which are reported to have been colder than ever before known.

At Atlantic City the average water temperature was about 8° below the normal and the lowest of record for July.[1]

PRECIPITATION.

The rainfall during the month was confined mostly to local storms as is usual during the midsummmer period. A few low areas, developing in the far West or Northwest, appear to have maintained their identity through the Mississippi Valley and thence eastward, and several Lows originating in the Great Plains pursued their usual courses to the Great Lakes and St. Lawrence Valley or over New England.

Thunderstorms were frequent and occasionally heavy and damaging during the first two decades over much of the middle and eastern portions of the country, this being particularly the case from the Ohio Valley and Lake region eastward to the Middle Atlantic States from the 2d to 4th, and in the Middle Plains and thence northeastward to the Great Lakes from the 5th to 7th. A general rainy condition overspread the Gulf States about the end of the first decade and extending northward and eastward brought substantial showers over much of the country from the Mississippi River eastward. Precipitation was again more or less general about the middle of the month from the upper Mississippi and lower Missouri Valleys eastward. About this time precipitation set in over Arizona and the far Southwest where the usual summer rains, frequently beginning during the last half of June, had been greatly delayed.

In the latter part of the second decade beneficial rains occurred over most States east of the Mississippi River and frequent showers continued in the far Southwest. During the last decade of the month there was generally much less rain in all districts, save in the far Southwest, than in the two preceding, the latter half especially being without material precipitation over large areas. Local showers continued during the last decade in Arizona and portions of surrounding States, some heavy falls being reported locally in Colorado about the middle of the decade.

The precipitation for the month was less than normal over extensive areas, particularly from the lower Ohio Valley and Great Lakes westward. The deficiency was large in portions of the middle Mississippi Valley and generally over the Plains region and the Southwest, the fall in Arizona and portions of surrounding States being in many cases little more than half the normal. However, only limited areas suffered seriously from lack of sufficient moisture. In portions of Illinois no rain fell after the 10th and drought became serious by the end of the month.

Over the upper Ohio drainage and thence eastward and northeastward the precipitation was well distributed during the month and very generally in excess of the usual fall for July, and considerable areas in the Gulf and south Atlantic States had amounts above the normal. The rainfall was quite unequally distributed, as might be expected when falling in connection with thunderstorms, this being particularly true of the Gulf and Atlantic States where in comparatively near-by localities the total monthly falls frequently varied as much as 10 inches. Likewise in portions of the middle West, large variations occurred, notably at Kansas City, Mo., the total fall for the month, 9.78 inches, was the greatest ever recorded at that station in July, while at other points in the State the monthly amounts were less than 1 inch.

RELATIVE HUMIDITY.

Despite frequent showers during the greater part of the month over most districts from the Mississippi Valley eastward, the percentage of relative humidity was very generally less than the average, and on the whole it was less than average over the greater part of the western mountain and Pacific coast States, some exceptions being noted, however, principally in central California, where values considerably above normal were observed. In the Plains States the averages were mainly above normal, with local exceptions.

SEVERE LOCAL STORMS.

On July 1, near Blair, Nebr., a small tornado was observed, but without material damage, and on the 16th in the same State press dispatches mentioned the occurrence of a tornado at Neligh, with heavy property damage.

Some severe hail and wind storms were reported during the month, a particularly severe one occurring in the vicinity of Cincinnati, Ohio, on the 8th. Growing crops were greatly damaged, fruit was beaten from trees, and small animals killed. Also near Rouse, Colo., on the 8th a severe hailstorm completely ruined crops over an area about 4 miles wide and 14 miles long, and near Pueblo, Colo., on the 15th a severe hailstorm caused much damage to growing crops.

In the vicinity of Cattaraugus County, N. Y., a severe wind and hailstorm on the 8th caused widespread damage. The fall of hail was unusually heavy; the ground, being covered, gave the appearance of a winter snowstorm.

Near Wichita, Kans., a severe wind and hail storm on the 31st caused damage to crops and buildings estimated at $800,000.

[1] See MONTHLY WEATHER REVIEW, June, 1920, 48: 352-353.

SPECIAL WARNINGS—WEATHER AND CROPS.

STORMS AND WEATHER WARNINGS.

By H. C. FRANKENFIELD, Supervising Forecaster.

[Aug. 24, 1920.]

Storm warnings.—There were no severe storms during the month, and no storm warnings were necessary. Small craft warnings for fresh to moderately strong winds were issued on July 3 for the Maine coast, on July 18 for the lower lakes, on July 23 for Lakes Michigan and Huron, and on July 24 for the New England coast. These warnings were justified.

From July 14 to 16, inclusive, low pressure prevailed over the southern Caribbean Sea and the north coast of South America, and some heavy rains and moderately strong winds were reported over the Panama Canal Zone.

Frost warnings.—Warnings of possible light frost in the cranberry bogs of New Jersey were issued on July 26 and 27. The lowest temperature reported was 37° on the morning of July 27, but no frosts occurred, so far as is known.

Special forecasts.—Special wind and weather forecasts were issued during the progress of the International Yacht races off Sandy Hook, N. J., and for the United States Army aeroplane flight from New York to Alaska.

WARNINGS IN OTHER DISTRICTS.

Chicago, Ill., District.—No frost warnings were issued during the month, except for northwestern Wyoming on the 6th.

Owing to the protracted dry weather in the far Northwest, the fire hazard had increased to such an extent that special fire-weather forecasts for Montana were requested by the district forester at Missoula, on the 20th inst., and were telegraphed daily during the remainder of the month.—*H. J. Cox.*

New Orleans, La., District.—No storm warnings were issued during the month and no storm occurred along the Gulf coast.

Mild weather prevailed generally with a greater number of rainy days over the southeastern portion of the district than the average.—*I. M. Cline.*

Denver, Colo., District.—No warnings of any kind were issued during the month.—*A. H. Thiessen.*

San Francisco, Calif., District.—The only warnings issued during the month were fire-weather warnings in California on the 22d. There were no storms on the coast.—*G. H. Willson.*

RIVERS AND FLOODS, JULY, 1920.

By ALFRED J. HENRY, Meteorologist in charge, River and Flood Division.

[Weather Bureau, Washington, Aug. 30, 1920.]

The floods of the month were mostly local and unimportant, except in the Carolinas, where general though moderate floods prevailed from the 20th to 25th. The usual details appear in Table No. I.

In a year of remarkably low water in the rivers of the Pacific drainage, it is rather unusual to find a stream of the magnitude of the Colorado discharging a large flood flow. The snow cover in the Grand and San Juan drainage, also in the upper Rio Grande drainage was exceptionally heavy and melting was delayed by low temperature until the season was so far advanced that melting was general and rapid in the higher elevations. As a result the Colorado was in flood from its source to its mouth and the upper Rio Grande was also in moderately high flood.

It seems probable that the Elephant Butte Dam of the Reclamation Service in New Mexico took care of the peak of the Rio Grande flood.

The following report on the Colorado flood has just come to hand:

REPORT ON RIVERS IN THE DENVER DISTRICT FOR MAY AND JUNE, 1920.

Colorado River.—At the end of March, 1920, reports from the tributary watersheds of the Colorado River indicated that the water content of the snow cover was greater than the normal in the Grand and Gunnison drainage areas and considerably greater in the Yampa, White, and San Juan areas. Interests affected were advised that the seasonal flow of the Colorado would be 30 per cent or more greater than the normal flow. Data available at the end of June showed that the discharge for the early part of the summer was about 45 per cent in excess of the normal for the past eight years. The flow for May exceeded the normal by only 5 per cent, while the flow for June was about 80 per cent greater than the normal.

Flood stages were reached at several stations on the upper tributaries early in the third decade of May and at the rating stations at Elgin, Utah, and Fruita, Colo., near the close of the month. On May 27 interests at Topock, Ariz., were advised that the highest previous stage would be exceeded at Topock. The highest previous stage, 23.3 feet, was passed on the 29th, and 24.4 feet was reached at Topock on June 2. The discharge at Yuma attained its maximum for the season, 190,000 second-feet, on June 8. On June 9 the discharge was 163,000 second-feet, and by the end of June the discharge had decreased to 74,000 second-feet. Frequent advices of the expected discharge were furnished to the public affected by high water in the lower Colorado. Owing to the absence of discharge data during the early part of May the estimates were too low. After the middle of May the estimates were generally remarkably close to the measured discharge at Yuma.

Rio Grande.—Moderate stages prevailed in the Rio Grande during April. The highest stages in the lower Rio Grande occurred, as usual, in May. At Espanola, N. Mex., a stage of 7.4 feet, or 1.6 feet below the flood stage, was reached on May 22. Three spans of the bridge near Espanola were washed away on that date. The flood stage was reached at Albuquerque, N. Mex., on May 24 and at San Marcial, N. Mex., on the 27th. Timely and accurate forecasts were issued for the lower stations; in several instances the actual stages being within one-tenth of a foot of the predicted stages.—*F. W. Brist.*

TABLE No. 1.—*Flood stages during month of July, 1920.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Atlantic Drainage:	*Feet.*			*Feet.*	
Neuse: Neuse, N. C.	14	20	22	17.2	21
Smithfield, N. C.	14	21	23	19.3	22
Cape Fear: Elizabethtown, N. C.	22	22	25	29.9	23
Fayetteville, N. C.	35	21	23	41.6	21
Haw: Moncure, N. C.	22	20	20	23.2	20
Santee: Rimini, S. C.	12	23	27	13.0	25,26
Ferguson, S. C.	12	25	30	12.7	27
Saluda: Pelzer, S. C.	7	22	22	7.0	22
Mississippi Drainage:					
Little Kanawha: Glenville, W. Va.	22	25	25	23.9	25
Des Moines: Ottumwa, Iowa	10	14	16	11.0	16
Grand: Brunswick, Mo.	10	(1)	19	12.3	1,2
West Gulf Drainage:					
Grand: State Bridge, Colo.	9	(1)	2	9.1	1
Pacific Drainage:					
Columbia: Marcus, Wash.	24	(1)	(2)	28.5	15-19

[1] Continued from June.
[2] Continued into August.

MEAN LAKE LEVELS DURING JULY, 1920.

By UNITED STATES LAKE SURVEY.

[Dated: Detroit, Mich., August 4, 1920.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.[1]			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during July, 1920:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	602.94	581.03	572.63	245.70
Above or below—				
Mean stage of June, 1920	+0.19	+0.17	+0.14	+0.14
Mean stage of July, 1919	+0.40	−0.31	−0.81	−2.05
Average stage for July, last 10 years	+0.50	+0.11	−0.19	−1.15
Highest recorded July stage	−0.88	−2.55	−1.79	−3.02
Lowest recorded July stage	+1.46	+1.13	+1.17	+1.11
Average relation of the July level to—				
June level	....	+0.10	−0.10	−0.10
August level	....	+0.10	+0.20	+0.30

[1] Lake St. Clair's level: In July, 575.63 feet.

EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS, JULY, 1920.

By J. B. KINCER, Meteorologist.

The weather during July was generally favorable to farming interests. As is usual in this month, precipitation was rather unevenly distributed geographically and was heavy in limited areas, particularly in portions of Florida, the extreme lower Mississippi Valley, and in some south Atlantic districts; the temperature averaged near the normal in most sections of the country. Soil moisture was mostly ample for crop needs generally, although at the close of the month rain was needed in many central and northern and some southern parts of the country. It was rather cool for best development of warm-weather crops during part of the month in most central and northern districts east of the Mississippi.

The absence of extended rainy periods was unusually favorable for harvesting and the thrashing of small grains, and the harvest of winter wheat was completed by the end of the month in nearly all central and eastern districts and in most of the Central Rocky Mountain States, under favorable conditions. At the close of the month the harvest of spring wheat was also under way in the eastern part of the belt, and this crop was nearing maturity in the western portion. Spring wheat, which was in very satisfactory condition at the beginning of the month in the principal producing areas, was favorably affected by the weather of the first half of the month generally. During the latter half, however, rust became prevalent in many districts, and there was insufficient moisture in some sections. The high temperatures during the last decade in the north-central portion of the belt was conducive to the propagation of black rust, and considerable complaint was received of damage from this disease. There was a falling off in the condition of the crop during the month in all States of the belt, except in North Dakota, the deterioration being marked in Minnesota, Nebraska, and Montana, and rather pronounced in South Dakota and Iowa. At the close of the month the condition of the crop continued above the average in North Dakota, and was near the average in Idaho and South Dakota, but elsewhere it was unsatisfactory, especially in Washington and Iowa.

The warmer weather that prevailed in central and southwestern districts the first of the month favorably affected corn, and that crop made satisfactory progress in nearly all sections; thereafter mostly favorable weather prevailed for this crop, although it was rather cool for best growth in some east-central and northeastern localities. The weather was very favorable in the lower Great Plains, and corn made excellent advance during the month in that area, where the condition at the end of the month was from 40 to 70 per cent above the 10-year average, as reported by the Bureau of Crop Estimates. Late in the month, however, rain was needed in much of the central and upper Mississippi Valley, and in the western portions of Kansas, Nebraska, and Oklahoma. At the close of the month the condition of corn was better than the 10-year average quite generally, except in portions of the South and Northeast and in Illinois, where it was somewhat below the average.

Cotton made steady improvement during the first two decades of the month under the influence of favorable weather conditions, but during the last decade the progress was variable, the weather being rather unfavorable for growth in Florida, Alabama, parts of Mississippi, and in Louisiana, where frequent rains and lack of sunshine caused shedding and weevil activity. At the close of the month the crop was in better condition than at the beginning in nearly all sections of the belt, the improvement being more substantial in Texas, Oklahoma, and Tennessee than in the other States. There was practically no change in the condition, however, in Louisiana.

Oats and barley did well during the month, and the weather was mostly favorable for harvest; while potatoes, truck, and minor crops made satisfactory advance in most sections, although near the close of the month rain was badly needed for gardens and vegetables in many central and north-central localities, in the far Northwest, and at some places in the South. Pastures, ranges, and fruit maintained mostly satisfactory condition during the month, and live stock continued in good shape.

CLIMATOLOGICAL TABLES.*

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, July, 1920.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	79.5	−0.6	Thomasville	99	1	Florence	57	27	5.28	−0.16	Citronelle	10.55	Eufaula	1.98
Arizona	80.6	+1.4	Gila Bend	120	8	Fort Valley	36	1	1.17	−1.29	Naco	3.85	4 stations	0.00
Arkansas	79.8	−0.3	Bee Branch	105	24	3 stations	52	9	4.22	+0.43	Brinkley	8.40	Bergman	0.85
California	71.7	−2.3	Greenland Ranch	125	31	Portola	26	12†	0.06	+0.02	Fort Bragg	1.42	158 stations	0.00
Colorado	66.0	0.0	2 stations	103	13	Crested Butte	21	6	1.73	−0.58	Hartsel	5.03	Dolores	0.00
Florida	80.9	−0.5	2 stations	99	3†	2 stations	59	29	7.16	+0.12	Ft. Myers	15.22	Sand Key	0.50
Georgia	79.3	−0.4	3 stations	101	1†	Blue Ridge	55	9†	5.95	+0.14	Millen	12.50	Alapaha	2.11
Hawaii (June)	73.7	+0.8	Mahukona	96	28	Volcano Observatory	48	9	2.68	−1.98	Holualoa	13.84	4 stations	0.00
Idaho	69.6	+2.1	Glenn's Ferry	111	26	Atlanta	20	25	0.32	−0.41	Kellogg	2.62	6 stations	0.00
Illinois	74.5	−1.4	11 stations	101	23†	2 stations	45	25†	2.46	−1.15	Flora	8.37	Sycamore	0.28
Indiana	72.8	−2.5	Wheatfield	103	23	Hickory Hill	39	26	3.77	+0.23	2 stations	7.86	Goshen	0.97
Iowa	72.3	−1.8	Clarinda	102	23	Earlham	45	27	4.22	+0.26	Stockport	7.49	Dubuque	1.11
Kansas	77.6	−0.4	Salina	110	23	Oberlin	46	10	3.33	−0.26	Lawrence	9.40	Independence	0.88
Kentucky	75.2	−1.5	2 stations	99	24	Franklin	44	27	3.85	−0.45	Maysville	7.92	Lexington	1 73
Louisiana	81.4	−0.4	Rayne	105	26	2 stations	63	10	8.18	+2.10	New Iberia	14.85	Ruston	2.52
Maryland-Delaware	73.0	−2.1	Cambridge, Md	98	24	Oakland, Md	37	5†	4.65	+0.20	Seaford, Del	7.96	Salisbury, Md	2.33
Michigan	65.4	−3.1	2 stations	98	23	3 stations	32	4†	3.21	−0.01	Maple Ridge	7.06	Grand Haven	1.12
Minnesota	67.9	−1.1	Baudette	100	28	2 stations	35	15†	2.88	−0.96	Tracy	7.34	Milaca	0.30
Mississippi	80.2	−0.5	Anguilla	101	3†	Anguilla	59	11†	5.98	+0.82	Laurel	12.92	Booneville	2.14
Missouri	76.3	−0.9	St. Charles	105	23	Goodland	47	9	3.25	−0.84	Kansas City	9.78	St. Louis No. 1	0.73
Montana	68.7	+3.1	Knowlton	105	27	Bowen	26	6	1.26	−0.26	Dillon	2.70	Poplar	0.17
Nebraska	74.3	−0.3	4 stations	105	21†	Harrison	38	8	2.73	−0.67	Genoa	7.82	Kimball	0.18
Nevada	72.7	+0.3	Logandale	113	18	San Jacinto	33	7	0.14	−0.24	McGill	1.25	15 stations	0.00
New England	67.4	−1.6	Madison, Me	97	12	Somerset, Vt	33	5†	3.75	−0.07	Bloomfield, Vt	10.02	Rockport, Mass	0.90
New Jersey	71.7	−1.9	Bridgeton	96	24	3 stations	42	18†	5.76	+0.96	Newark	16.25	Asbury Park	1.20
New Mexico	71.6	−0.2	2 stations	106	5	Senorito (near)	30	5	1.70	−0.83	Nogal (near)	6.54	Los Lunas (near)	T.
New York	67.1	−2.7	2 stations	93	13†	Indian Lake	35	27	4.94	+1.02	Port Jervis No. 1	9.46	Farmingdale	2.65
North Carolina	75.3	−1.2	2 stations	100	3†	Banners Elk	44	29	6.02	+0.06	Southern Pines	12.14	Settle	1.95
North Dakota	68.3	+0.8	Mandan	103	22	2 stations	37	31	2.15	−0.46	Fullerton	4.89	3 stations	0.78
Ohio	70.4	−3.4	Clarington	98	23	Medina	40	5	4.50	+0.44	Green	8.85	Oberlin	1.25
Oklahoma	80.7	−0.1	3 stations	109	1†	Stillwater	51	7	3.27	+0.26	Bristow	8.00	Durant	0.69
Oregon	67.0	+0.5	Umatilla	110	27	Blitzen	16	12	0.56	−0.01	Government Camp	2.55	Maury	T.
Pennsylvania	69.5	−2.7	Gettysburg	96	23	West Bingham	33	27	4.37	+0.34	Milford	10.70	Creekside	1.27
Porto Rico	79.0	+0.2	Utuado	95	2†	Toro Negro Dam	59	29	5.38	−1.21	Mayaguez	16.26	Guanica Central	0.15
South Carolina	78.9	−0.9	2 stations	102	4†	2 stations	53	29	5.60	−0.30	Effingham	12.23	Newberry	2.50
South Dakota	71.4	−1.4	Dowling	109	22	Spearfish	35	8	2.29	−0.57	Dumont	5.58	Cedar Butte	0.26
Tennessee	76.6	−1.0	4 stations	98	3†	Mountain City	45	28†	3.83	−0.68	Covington	8.94	Tazewell	1.41
Texas	82.9	0.0	Claytonville	111	29	3 stations	54	2†	2.59	−0.14	Alvin	10.23	4 stations	0.00
Utah	72.2	+1.5	St. George	109	7	Black's Fork	28	13	0.57	−0.36	Jozella Ranch	2.93	7 stations	0.00
Virginia	73.0	−3.1	Buchanan	98	24	Burkes Garden	39	26	4.73	+0.25	Williamsburg	9.03	Woodstock	2.03
Washington	68.2	+2.1	Omak	108	28	2 stations	32	24†	0.87	+0.80	Waterville	2.27	2 stations	0.00
West Virginia	70.1	−3.0	Charleston	99	23†	3 stations	40	5†	4.84	+0.52	Parsons	8.94	Wardensville	2.34
Wisconsin	66.7	−2.4	3 stations	98	21†	Koepenick	35	24	2.37	−1.50	Twin Lakes Dam	6.00	Brodhead	0.67
Wyoming	65.5	+0.7	Emblem	104	29	Riverside	22	7	0.82	−0.47	Rocky Point	2.62	2 stations	0.00

* For description of tables and charts see this REVIEW, January, 1920, p. 54.

† Other dates also.

TABLE I.—*Climatological data for Weather Bureau Stations, July, 1920.*

Districts and stations.	Elevation of instruments: Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Pressure: Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Temperature of the air: Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation: Total.	Departure from normal.	Days with 0.01 inch or more.	Wind: Total movement.	Prevailing direction.	Maximum velocity: Miles per hour.	Direction.	Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, ice, and sleet on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.		In.	In.		Miles.								0-10	In.	In.
New England.							**68.0**	**− 0.7**										**77**	**3.39**	**− 0.2**										**5.5**		
Eastport	76	67	85	29.84	29.92	−0.01	59.9	+ 0.1	79	6	69	47	5	51	29	55	53	82	1.23	− 2.2	11	6,376	s.	30	e.	19	7	12	12	6.1	0.0	0.0
Greenville, Me.	1,070	6	......	28.76	29.92	......	63.6	......	83	11	74	42	2	53	38	......	......	......	4.46	......	20	......	......	......	......	......	9	12	10	......	0.0	0.0
Portland, Me.	103	82	117	29.83	29.95	.00	67.6	0.4	86	13	76	53	26	60	27	61	57	72	3.67	+ 0.4	10	6,077	s.	23	sw.	24	16	6	9	4.5	0.0	0.0
Concord	288	70	79	29.64	29.94	− .02	69.0	− 0.1	90	14	80	45	27	58	35	......	......	......	3.24	− 0.6	9	3,652	nw.	24	w.	4	7	15	9	5.8	0.0	0.0
Burlington	404	11	48	29.49	29.92	− .02	66.7	− 1.5	85	14	75	49	2	58	28	......	......	......	4.85	+ 1.1	17	7,021	s.	40	s.	7	6	10	15	6.5	0.0	0.0
Northfield	876	12	60	29.01	29.94	.00	64.3	− 2.3	85	14	75	43	27	53	36	60	57	78	3.70	0.0	20	4,723	s.	25	se.	7	1	16	14	7.2	0.0	0.0
Boston	125	115	188	29.82	29.95	− .01	72.4	+ 1.1	90	13	81	56	27	63	25	65	61	70	1.56	− 1.8	6	7,329	sw.	27	nw.	4	11	15	5	5.2	0.0	0.0
Nantucket	12	14	90	29.97	29.98	.00	67.2	− 0.3	79	9	73	56	5	61	19	64	62	88	1.98	− 0.7	8	11,193	sw.	42	sw.	24	13	8	10	5.0	0.0	0.0
Block Island	26	11	46	29.95	29.98	+ .01	67.7	− 0.4	80	13	73	57	26	62	17	65	64	93	2.45	− 0.9	8	10,876	sw.	46	sw.	24	15	5	11	5.2	0.0	0.0
Providence	160	215	251	29.80	29.97	.00	71.4	− 2.0	90	13	80	53	26	62	23	63	59	69	3.00	− 0.5	7	8,195	sw.	53	nw.	4	10	15	6	4.9	0.0	0.0
Hartford	159	122	140	29.80	29.97	.00	70.6	− 1.0	88	13	80	52	27	61	27	63	60	72	6.70	+ 2.6	10	5,698	sw.	40	nw.	4	10	9	12	5.6	0.0	0.0
New Haven	106	74	153	29.86	29.98	+ .01	70.8	− 1.1	90	13	79	53	27	62	24	64	60	71	4.93	+ 0.2	9	6,401	sw.	35	w.	24	15	8	8	4.5	0.0	0.0
Middle Atlantic States.							**72.6**	**− 2.0**										**74**	**4.32**	**0.0**										**4.8**		
Albany	97	102	115	29.84	29.94	− .02	70.0	− 2.0	88	14	80	51	27	60	30	63	59	71	4.85	+ 1.0	16	5,044	s.	34	s.	7	11	14	6	4.8	0.0	0.0
Binghamton	871	10	84	29.06	29.97	.00	68.6	− 1.3	87	14	79	45	27	58	34	......	......	......	6.30	+ 2.8	13	3,922	w.	34	nw.	23	6	16	9	6.1	0.0	0.0
New York	314	414	454	29.65	29.98	.00	72.5	− 1.0	88	13	80	55	26	65	22	65	61	72	4.78	+ 0.2	13	11,359	s.	60	w.	14	6	18	7	5.4	0.0	0.0
Harrisburg	374	94	104	29.61	30.00	+ .02	73.0	− 1.5	90	23	82	53	27	64	27	64	59	66	4.02	+ 0.2	11	4,368	s.	34	sw.	7	10	14	7	4.8	0.0	0.0
Philadelphia	117	123	190	29.87	30.00	+ .02	75.6	− 0.2	91	31	84	56	26	67	25	67	62	68	3.52	− 0.8	11	6,398	s.	25	s.	7	7	18	6	4.9	0.0	0.0
Reading	325	81	98	29.64	29.99	......	73.5	......	90	14	84	52	27	63	26	65	60	66	3.67	− 0.6	11	4,477	sw.	31	nw.	14	14	8	9	5.0	0.0	0.0
Scranton	805	111	119	29.14	29.99	+ .01	69.6	− 2.2	89	14	80	47	27	59	30	63	60	73	5.42	+ 1.6	13	4,991	sw.	33	sw.	14	5	19	7	5.8	0.0	0.0
Atlantic City	52	37	48	29.94	29.99	+ .01	70.0	− 2.5	85	8	76	54	27	64	22	65	63	81	1.86	− 1.9	11	5,158	sw.	23	w.	24	16	10	5	3.7	0.0	0.0
Cape May	18	13	49	30.02	30.04	+ .06	70.6	− 2.8	85	8	77	55	27	64	20	66	64	85	3.42	− 0.4	8	5,261	s.	48	nw.	3	15	10	6	3.8	0.0	0.0
Sandy Hook	22	10	57	29.96	29.98	......	72.4	......	88	13	80	59	26	65	21	67	64	80	4.79	......	10	9,357	s.	48	nw.	24	8	16	7	5.1	0.0	0.0
Trenton	190	159	183	29.78	29.98	......	73.0	......	90	13	83	53	26	63	26	66	62	73	2.16	− 2.6	9	7,692	s.	40	nw.	31	10	13	8	5.2	0.0	0.0
Baltimore	123	100	113	29.87	29.99	+ .01	76.0	− 1.3	93	31	84	56	27	68	27	67	63	67	4.94	+ 0.1	10	4,940	s.	21	sw.	7	12	12	7	4.8	0.0	0.0
Washington	112	62	85	29.88	30.00	.00	75.0	− 1.8	95	24	85	54	26	65	29	67	64	72	5.71	+ 1.1	12	3,852	s.	41	nw.	24	8	13	10	5.4	0.0	0.0
Lynchburg	681	153	188	29.30	30.02	+ .01	74.8	− 2.5	94	24	86	53	28	64	33	67	64	74	4.82	+ 0.8	12	4,485	sw.	44	w.	14	16	12	3	4.0	0.0	0.0
Norfolk	91	170	205	29.94	30.03	+ .03	76.4	− 2.0	92	24	85	62	30	68	25	69	67	78	4.33	− 1.5	11	8,659	s.	51	n.	3	10	13	8	4.8	0.0	0.0
Richmond	144	11	52	29.88	30.02	+ .01	75.4	− 3.8	94	24	85	56	28	66	27	69	66	79	6.05	+ 1.6	11	4,992	s.	37	sw.	19	8	10	13	5.8	0.0	0.0
Wytheville	2,304	49	56	27.72	30.03	+ .02	69.4	− 3.2	86	23	80	50	29	59	31	63	61	77	3.25	− 1.2	12	3,704	w.	21	sw.	2	21	9	1	2.8	0.0	0.0
South Atlantic States.							**78.0**	**− 1.0**										**79**	**5.42**	**− 0.7**										**5.6**		
Asheville	2,255	70	84	27.77	30.06	+ .04	71.6	− 0.1	89	24	81	56	17	62	26	65	62	80	3.75	− 1.1	13	4,043	nw.	24	nw.	4	11	15	5	5.2	0.0	0.0
Charlotte	779	55	62	29.21	30.03	+ .01	77.8	− 0.9	95	3	88	57	27	68	27	69	66	73	4.11	− 1.4	14	3,255	sw.	32	w.	15	10	7	14	5.4	0.0	0.0
Hatteras	11	12	50	30.04	30.05	+ .04	75.8	− 2.8	87	4	80	67	6	71	18	73	72	88	5.09	− 1.0	14	10,515	sw.	39	n.	3	7	9	15	6.5	0.0	0.0
Manteo	12	5	42	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Raleigh	376	103	110	29.64	30.03	+ .01	76.4	− 2.1	93	3	86	56	27	67	28	69	67	79	6.00	− 0.1	15	5,203	sw.	29	s.	11	9	10	12	5.8	0.0	0.0
Wilmington	78	81	91	29.98	30.06	+ .05	77.8	− 0.9	95	4	86	58	28	70	21	72	69	80	7.23	+ 0.3	15	5,717	sw.	24	sw.	7	8	11	12	5.7	0.0	0.0
Charleston	48	11	92	30.01	30.06	+ .03	80.0	− 1.3	98	3	87	67	28	73	25	74	71	77	4.69	− 2.6	17	7,510	sw.	38	nw.	2	7	9	15	6.3	0.0	0.0
Columbia, S. C.	351	41	57	29.68	30.05	+ .03	80.0	− 1.1	96	25	89	60	29	70	25	70	67	75	3.36	− 2.7	9	5,045	sw.	30	sw.	2	8	10	13	5.7	0.0	0.0
Greenville, S. C.	1,039	113	122	28.96	30.03	......	76.6	......	93	4	86	61	16	68	25	68	66	75	7.90	......	11	4,994	sw.	56	n.	16	11	11	9	5.1	0.0	0.0
Augusta	180	62	77	29.85	30.04	+ .02	80.4	− 0.1	97	4	90	62	29	70	27	72	69	78	7.20	+ 1.0	13	3,831	s.	28	sw.	21	11	9	11	5.3	0.0	0.0
Savannah	65	150	194	30.00	30.06	+ .03	80.2	− 0.3	96	25	89	64	28	72	26	73	71	82	7.30	+ 1.1	16	7,574	sw.	38	n.	16	4	17	10	6.3	0.0	0.0
Jacksonville	43	209	245	30.03	30.08	+ .05	80.2	− 0.7	92	5	88	67	28	72	22	74	72	82	5.47	− 0.7	16	8,283	sw.	58	w.	4	8	22	1	4.5	0.0	0.0
Florida Peninsula.							**82.1**	**− 0.1**										**76**	**6.45**	**0.0**										**5.4**		
Key West	22	10	64	30.04	30.06	+ .03	83.9	+ 0.2	90	25	88	76	26	79	12	76	73	72	0.54	− 3.0	7	7,257	e.	32	nw.	26	9	17	5	4.9	0.0	0.0
Miami	25	71	79	30.07	30.10	......	81.2	− 0.7	88	27	86	70	23	76	17	75	73	76	6.61	− 0.6	16	5,891	e.	30	w.	23	6	17	8	5.9	0.0	0.0
Sand Key	23	89	72	30.02	30.05	+ .02	82.0	......	89	2	84	74	21	80	9	76	73	74	0.50	......	5	8,906	se.	38	se.	21	12	17	2	4.3	0.0	0.0
Tampa	35	79	92	30.05	30.08	+ .04	81.3	+ 0.1	93	9	89	68	13	73	23	74	72	81	12.20	+ 3.8	19	4,035	w.	30	ne.	13	2	22	7	6.5	0.0	0.0
East Gulf States.							**79.7**	**− 0.6**										**79**	**5.47**	**+ 0.2**										**6.2**		
Atlanta	1,174	190	216	28.85	30.06	+ .04	77.3	− 0.3	91	5	86	65	11	69	23	70	67	76	5.95	+ 1.2	15	5,934	nw.	34	nw.	2	6	8	17	6.4	0.0	0.0
Leesburg	279	10	55	29.78	30.08	......	79.6	......	94	1	89	62	29	70	26	72	70	79	6.47	......	10	4,198	sw.	39	w.	10	4	9	18	7.3	0.0	0.0
Macon	370	78	87	29.66	30.06	+ .04	79.6	− 0.1	95	25	89	62	30	70	26	71	68	74	2.78	− 1.8	13	3,871	s.	29	nw.	4	7	10	14	6.3	0.0	0.0
Thomasville	273	49	58	29.78	30.07	+ .04	80.4	− 1.4	96	3	90	62	29	71	25	73	71	78	3.38	− 1.9	16	2,950	sw.	19	sw.	7	3	16	12	6.5	0.0	0.0
Pensacola	56	149	185	30.00	30.07	+ .05	79.6	− 1.8	92	26	85	68	11	74	18	74	72	78	6.74	− 0.5	17	7,975	sw.	38	nw.	11	3	13	15	6.9	0.0	0.0
Anniston	741	9	57	29.30	30.08	+ .06	77.7	− 0.2	98	24	88	62	28	68	24	......	......	......	4.65	− 0.1	15	2,728	se.	29	ne.	4	12	14	5	4.5	0.0	0.0
Birmingham	700	11	48	29.32	30.07	+ .06	78.8	− 2.7	93	24	87	66	27	70	22	71	69	80	4.63	− 0.1	14	3,472	s.	26	nw.	25	4	18	9	6.1	0.0	0.0
Mobile	57	125	161	30.00	30.06	+ .05	81.0	+ 0.5	94	8	88	70	11	74	21	75	73	80	7.04	0.0	18	5,541	sw.	46	ne.	25	3	19	9	6.6	0.0	0.0
Montgomery	223	100	112	29.82	30.06	+ .04	80.8	− 0.2	95	25	89	67	29	72	22	73	69	74	3.35	− 1.3	9	4,326	sw.	29	sw.	13	11	12	8	5.1	0.0	0.0
Corinth	469	6	......	......	......	......	80.0	......	96	24	90	60	27	70	30	......	......	......	6.44	......	13	......	s.	......	......	......	7	22	2	......	0.0	0.0
Meridian	375	85	93	29.66	30.04	+ .02	79.6	− 0.4	94	3	88	65	30	71	25	72	70	80	7.02	+ 2.5	12	3,357	sw.	26	w.	6	5	18	8	6.3	0.0	0.0
Vicksburg	247	65	74	29.78	30.05	+ .05	80.0	− 0.4	94	24	88	68	28	72	21	73	72	85	8.47	+ 4.0	10	3,980	sw.	34	nw.	7	3	14	14	6.4	0.0	0.0
New Orleans	53	76	84	30.00	30.05	+ .05	82.3	+ 1.0	93	25	89	67	11	75	21	76	74	81	6.20	− 0.3	18	3,154	sw.	36	e.	9	3	17	11	6.5	0.0	0.0
West Gulf States.							**81.7**	**− 0.2**										**75**	**2.51**	**− 0.7**										**4.6**		
Shreveport	249	77	93	29.76	30.02	+ .04	81.5	− 0.6	96	2	90	66	10	73	23	74	71	77	4.02	+ 0.3	9	4,328	se.	34	e.	27	14	13	4	4.2	0.0	0.0
Bentonville	1,303	11	44	28.67	30.00	+ .03	76.6	− 1.9	96	3	87	55	9	66	31	......	......	......	2.83	− 1.5	6	2,523	e.	22	sw.	14	17	10	4	4.2	0.0	0.0
Fort Smith	457	79	94	29.52	29.98	+ .01	81.4	+ 0.4	102	3	91	64	10	72	28	72	69	71	1.92	− 1.9	11	4,284	e.	36	nw.	16	15	11	5	4.0	0.0	0.0
Little Rock	357	139	147	29.64	30.01	+ .02	80.4	− 0.2	99	3	89	61	27	71	24	73	70	76	3.06	− 0.9	10	4,542	s.	26	ne.	19	9	17	5	4.7	0.0	0.0
Brownsville	57	4	26	......	......	......	85.0	......	99	22	95	72	29	75	24	......	......	......	2.18	......	2	......	se.	......	......	......	......	......	......	......	0.0	0.0
Corpus Christi	20	69	77	29.99	30.01	+ .05	82.8	+ 0.1	91	29	88	75	16	77	15	77	75	81	0.19	− 1.5	4	10,083	se.	36	s.	5	15	14	2	3.6	0.0	0.0
Dallas	512	109	117	29.46	29.99	......	83.2	......	99	16	93	66	10	74	23	......	......	......	1.89	......	5	5,324	s.	36	nw.	6	12	17	2	4.5	0.0	0.0
Fort Worth	670	106	114	29.26	29.96	.00	82.8	− 0.9	98	2	93	64	9	72	27	72	68	68	3.49	+ 0.4	6	6,047	s.	50	nw.	20	14	15	2	4.2	0.0	0.0
Galveston	54	106	114	29.98	30.04	+ .06	82.2	− 0.8	89	20	87	71	15	78	15	76	74	79	3.21	− 0.8	11	6,869	s.	24	n.	22	10	14	7	4.8	0.0	0.0
Groesbeck	461	11	56	29.50	29.97	......	82.7	......	98	16	94	67	9	72	27	74	71	76	1.41	......	6	5,791	s.	42	n.	6	8	18	5	5.2	0.0	0.0
Houston	138	111	121	29.88	30.02	......	83.2	+ 0.2	97	27	92	70	9	74	23	......	......	......	3.84	......	12	4,505	s.	27	se.	13	11	18	2	4.5	0.0	0.0
Palestine	510	64	72	29.49	30.01	+ .04	81.2	− 0.3	96	16	91	65	10	72	27	73	70	76	3.71	+ 0.7	6	4,287	sw.	34	nw.	8	6	13	12	5.9	0.0	0.0
Port Arthur	34	58	66	29.98	30.02	......	81.6	......	93	26	88	70	22	75	23	76	74	80	8.60	......	15	5,728	sw.	28	e.	29	9	15	7	5.9	0.0	0.0
San Antonio	701	119	132	29.28	30.00	+ .05	83.8	+ 1.4	98	22	94	71	5	74	24	73	69	69	0.39	− 1.8	5	4,891	se.	34	nw.	29	16	14	1	3.9	0.0	0.0
Taylor	582	55	63	29.43	30.04	+ .08	83.2	+ 0.5	98	20	94	68	4	73	26	......	......	......	2.24	− 0.4	7	4,915	s.	31	ne.	9	8	18	5	5.2	0.0	0.0

TABLE I.—*Climatological data for Weather Bureau Stations, July, 1920*—Continued.

Districts and stations.	Elevation of instruments. Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Pressure. Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Temperature of the air. Mean max. + mean min. ÷ 2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation. Total.	Departure from normal.	Days with 0.01 inch or more.	Wind. Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Direction.	Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, ice, and sleet on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.		In.	In.		Miles.								0–10	In.	In.
Ohio Valley and Tennessee.							**74.0**	**− 2.4**										**71**	**3.69**	**− 0.3**										**5.0**		
Chattanooga	762	189	213	29.26	30.06	+ .04	76.8	− 0.5	92	24	86	63	27	68	24	70	67	78	6.39	+ 2.5	14	4,402	sw.	39	nw.	3	3	19	9	6.1	0.0	0.0
Knoxville	996	102	111	29.00	30.03	+ .01	76.2	0.0	92	24	86	60	29	66	26	68	64	73	2.19	− 2.0	8	3,901	sw.	26	sw.	7	6	8	17	6.6	0.0	0.0
Memphis	399	76	97	29.64	30.06	+ .06	79.4	− 1.3	92	3	86	65	28	72	23	72	69	74	3.55	0.0	10	4,984	sw.	40	nw.	1	11	12	8	5.3	0.0	0.0
Nashville	546	168	191	29.47	30.04	+ .03	77.6	− 1.8	93	24	87	62	27	68	25	68	65	70	3.00	− 1.4	10	5,120	w.	40	s.	5	13	13	5	4.6	0.0	0.0
Lexington	989	193	230	28.99	30.03	+ .02	74.4	− 2.2	93	24	83	53	26	66	26	....	....	....	1.73	− 2.7	10	8,662	sw.	37	nw.	3	11	14	6	4.5	0.0	0.0
Louisville	525	219	255	29.46	30.04	+ .04	76.2	− 2.4	95	24	86	57	27	67	27	66	62	67	2.13	− 1.6	9	7,179	sw.	44	nw.	3	16	9	6	3.8	0.0	0.0
Evansville	431	139	175	29.56	30.02	+ .02	77.8	− 1.5	96	24	88	60	27	68	26	68	64	67	2.86	− 1.0	9	6,739	sw.	43	ne.	18	5	24	2	5.3	0.0	0.0
Indianapolis	822	194	230	29.14	30.02	+ .03	73.4	− 2.8	95	23	83	56	26	64	25	65	60	66	4.51	+ 0.4	11	7,068	sw.	58	nw.	3	10	15	6	4.7	0.0	0.0
Royal Center	736	11	55	29.22	30.00	......	70.0	......	96	23	82	48	27	58	32	64	60	72	3.92	......	9	6,032	n.	38	sw.	13	10	15	6	5.0	0.0	0.0
Terre Haute	575	96	129	29.38	29.99	......	75.2	......	98	23	86	56	27	65	28	65	60	64	5.39	......	7	5,901	sw.	27	nw.	24	6	19	6	5.3	0.0	0.0
Cincinnati	628	11	51	29.35	30.02	+ .02	72.8	− 1.4	94	23	83	52	27	62	30	66	61	68	3.19	− 0.4	11	4,437	sw.	27	s.	6	15	10	6	4.2	0.0	0.0
Columbus	824	179	222	29.16	30.02	+ .02	71.0	− 4.3	92	23	80	54	26	62	25	64	61	75	5.18	+ 1.5	12	6,575	sw.	49	nw.	31	16	6	9	4.2	0.0	0.0
Dayton	899	181	216	29.04	29.97	......	72.3	− 3.9	94	23	82	54	26	62	29	63	59	67	3.76	+ 0.5	10	6,240	sw.	33	ne.	30	17	7	7	3.9	0.0	0.0
Elkins	1,947	59	67	28.03	30.03	+ .02	66.4	− 4.1	87	24	78	43	26	55	32	61	59	82	5.27	+ 0.6	12	2,991	w.	22	sw.	24	5	13	13	6.5	0.0	0.0
Parkersburg	638	77	84	29.39	30.04	+ .03	72.0	− 3.6	92	23	82	53	5	62	28	64	61	72	4.56	− 0.1	13	3,404	se.	32	nw.	8	15	10	6	4.5	0.0	0.0
Pittsburgh	842	353	410	29.12	30.00	.00	70.4	− 4.2	88	30	79	51	26	62	24	63	59	69	3.29	− 1.1	12	7,186	sw.	41	nw.	18	9	11	11	5.8	0.0	0.0
Lower Lake Region.							**68.4**	**− 3.3**										**70**	**3.80**	**+ 0.4**										**5.5**		
Buffalo	767	247	280	29.15	29.97	.00	66.1	− 4.1	81	6	72	53	26	60	21	61	57	74	4.50	+ 1.1	13	11,354	sw.	56	w.	23	7	12	12	6.4	0.0	0.0
Canton	448	10	61	29.44	29.90	......	66.0	− 4.5	85	13	75	46	2	57	26	....	....	....	4.98	+ 1.8	19	6,750	sw.	37	sw.	30	5	15	11	6.0	0.0	0.0
Oswego	335	76	91	29.58	29.94	− .02	65.6	− 4.0	86	13	73	50	4	58	26	60	57	76	4.50	+ 1.3	14	5,780	w.	26	ne.	25	11	7	13	5.5	0.0	0.0
Rochester	523	86	102	29.41	29.97	.00	67.8	− 2.6	88	13	77	49	16	59	25	60	56	67	2.93	− 0.2	13	5,877	sw.	32	w.	15	7	7	17	6.4	0.0	0.0
Syracuse	597	97	113	29.33	29.97	.00	68.0	− 2.8	87	13	76	51	16	60	28	....	....	....	3.82	+ 0.1	16	7,430	nw.	45	nw.	31	6	17	8	5.6	0.0	0.0
Erie	714	130	166	29.22	29.98	.00	68.6	− 3.2	86	13	76	52	17	61	23	62	58	71	3.84	+ 0.6	13	8,609	nw.	43	w.	18	7	16	8	5.3	0.0	0.0
Cleveland	762	190	201	29.19	30.00	+ .01	69.2	− 3.3	91	23	76	52	27	62	27	62	58	69	3.32	− 0.2	8	8,271	sw.	44	n.	18	10	10	11	5.5	0.0	0.0
Sandusky	629	62	103	29.31	29.98	− .01	70.7	− 2.9	93	23	79	54	27	62	28	....	....	....	2.01	− 1.8	9	7,552	sw.	33	ne.	25	7	15	9	5.5	0.0	0.0
Toledo	628	208	243	29.32	29.99	.00	70.6	− 3.1	93	23	80	53	25	61	27	62	58	65	4.46	+ 1.2	11	8,640	sw.	44	sw.	8	14	12	5	4.7	0.0	0.0
Fort Wayne	856	113	124	29.10	30.01	......	70.4	− 3.1	94	23	81	54	5	60	26	63	58	68	6.28	......	11	5,780	sw.	34	sw.	13	12	15	4	4.5	0.0	0.0
Detroit	730	218	245	29.21	29.99	+ .01	69.6	− 2.4	92	23	78	53	25	61	27	61	57	68	3.65	+ 0.2	10	7,413	w.	38	sw.	13	6	21	4	5.6	0.0	0.0
Upper Lake Region.							**65.1**	**− 2.9**										**72**	**2.62**	**− 0.5**										**4.8**		
Alpena	609	13	92	29.31	29.97	.00	62.4	− 3.4	87	12	72	43	16	53	33	58	55	76	1.96	− 1.1	10	8,161	nw.	36	se.	18	8	15	8	5.5	0.0	0.0
Escanaba	612	54	60	29.31	29.96	− .01	62.6	− 3.9	84	2	71	46	25	54	28	58	54	75	2.54	− 0.8	11	6,894	s.	33	n.	18	14	13	4	3.5	0.0	0.0
Grand Haven	632	54	89	29.30	29.97	− .01	64.6	− 5.1	83	11	74	46	25	56	25	59	55	70	1.12	− 1.5	10	7,319	sw.	34	sw.	23	14	10	7	4.4	0.0	0.0
Grand Rapids	707	70	87	29.22	29.98	.00	68.9	− 3.7	93	23	80	48	25	58	30	61	55	63	3.60	+ 1.0	10	3,705	w.	38	w.	2	8	16	7	5.1	0.0	0.0
Houghton	684	62	99	29.24	29.96	.00	62.4	− 2.8	85	28	72	45	4	53	28	....	....	....	2.49	− 0.6	7	6,910	w.	52	nw.	13	11	11	9	5.0	0.0	0.0
Lansing	878	11	62	29.05	29.98	......	67.3	− 3.8	94	23	79	46	5	55	31	61	57	72	3.01	− 0.2	11	3,364	sw.	19	sw.	29	6	10	15	6.2	0.0	0.0
Ludington	637	60	66	29.29	29.98	......	61.8	......	79	1	69	46	5	54	22	59	56	81	2.15	......	8	6,516	s.	28	s.	28	18	8	5	3.6	0.0	0.0
Marquette	734	77	111	29.19	29.99	+ .03	62.2	− 2.7	85	13	71	46	18	54	34	56	51	69	4.62	+ 1.5	10	6,522	nw.	35	nw.	13	9	11	11	5.8	0.0	0.0
Port Huron	638	70	120	29.28	29.97	− .01	66.4	− 2.6	88	23	76	48	16	57	31	61	58	75	2.73	0.0	12	6,987	sw.	30	nw.	23	6	20	5	5.2	0.0	0.0
Saginaw	641	69	77	29.29	29.98	......	67.2	......	91	23	78	48	25	57	30	60	56	68	1.96	− 1.7	8	5,349	sw.	28	sw.	13	6	16	9	5.5	0.0	0.0
Sault Sainte Marie	614	11	52	29.27	29.96	− .01	60.7	− 1.2	84	11	70	43	5	51	32	56	53	78	2.00	− 0.8	9	5,572	nw.	36	nw.	31	10	20	1	4.5	0.0	0.0
Chicago	823	140	310	29.13	30.00	+ .02	71.5	− 0.9	98	23	80	57	25	64	28	62	57	66	1.61	− 2.0	6	7,141	w.	44	w.	23	16	11	4	3.9	0.0	0.0
Green Bay	617	109	144	29.31	29.97	.00	67.2	− 2.3	86	30	76	51	16	58	25	60	56	71	3.49	0.0	13	7,740	s.	46	w.	2	12	13	6	5.4	0.0	0.0
Milwaukee	681	125	139	29.26	29.99	+ .02	67.7	− 2.0	97	23	76	53	25	60	33	60	55	67	0.80	− 2.2	10	6,419	ne.	32	w.	23	12	9	10	5.0	0.0	0.0
Duluth	1,133	11	47	28.78	29.98	+ .03	62.8	− 3.2	84	28	72	44	15	53	30	58	55	76	4.82	+ 1.2	7	8,109	ne.	38	n.	23	16	9	6	4.1	0.0	0.0
North Dakota.							**69.5**	**+ 0.4**										**68**	**2.28**	**− 0.6**										**3.7**		
Moorhead	940	8	57	29.00	29.99	+ .05	69.0	+ 0.3	90	17	81	48	15	57	32	63	59	73	2.92	− 0.8	8	4,491	n.	30	ne.	13	25	4	2	2.3	0.0	0.0
Bismarck	1,674	8	57	28.27	30.03	+ .10	71.0	+ 0.8	102	22	83	51	13	59	36	61	56	64	2.72	+ 0.6	9	6,011	nw.	32	ne.	13	14	13	4	3.9	0.0	0.0
Devils Lake	1,482	11	44	28.43	29.98	+ .05	67.2	− 0.9	91	27	79	43	31	55	32	59	54	67	2.51	− 1.3	5	6,132	nw.	34	ne.	16	17	12	2	3.7	0.0	0.0
Ellendale	1,457	10	56	28.46	30.01	......	67.4	......	98	22	79	49	14	56	36	62	59	77	2.63	......	10	7,733	nw.	58	nw.	3	7	18	6	5.3	0.0	0.0
Grand Forks	835	12	89	......	......	......	......	......	....	....	....	....	....	....	....	....	....	....	......	......	....	......	......	....	......	....	....	....	....	....	....	....
Williston	1,878	41	48	28.02	29.96	+ .04	70.8	+ 1.4	98	27	83	47	9	58	34	60	54	60	0.96	− 1.1	9	5,213	n.	36	w.	22	19	11	1	3.4	0.0	0.0
Upper Mississippi Valley.							**73.5**	**− 1.9**										**65**	**2.11**	**− 1.5**										**4.3**		
Minneapolis	918	102	208	28.99	29.95	......	70.6	......	92	22	80	55	14	61	25	....	....	....	1.30	− 2.5	8	7,216	w.	38	n.	23	9	14	8	5.0	0.0	0.0
St. Paul	837	236	261	29.09	29.98	+ .03	70.2	− 1.9	90	22	80	54	14	61	24	....	....	....	1.35	− 2.0	8	7,681	sw.	50	se.	4	16	11	4	3.7	0.0	0.0
La Crosse	714	11	48	......	30.00	+ .04	70.2	− 2.4	92	23	80	52	16	60	29	....	....	....	1.05	− 3.0	7	2,843	s.	15	w.	23	15	11	5	....	0.0	0.0
Madison	974	70	78	28.97	29.99	+ .02	69.1	− 3.3	91	23	78	52	25	60	25	61	56	66	1.39	− 2.6	6	5,636	sw.	34	ne.	24	12	11	8	4.8	0.0	0.0
Wausau	1,247	4	....	28.66	29.97	......	65.5	......	88	23	76	45	25	55	32	....	....	....	1.12	......	8	......	nw.	....	......	....	13	12	6	4.3	0.0	0.0
Charles City	1,015	10	49	28.94	30.00	+ .04	70.0	− 3.5	91	22	80	52	26	59	30	63	59	70	2.92	− 0.7	11	3,803	nw.	24	sw.	12	12	16	3	4.5	0.0	0.0
Davenport	606	71	79	29.35	30.00	+ .03	73.4	− 2.0	96	23	83	54	5	63	27	65	60	65	2.19	− 1.4	7	4,714	sw.	23	w.	23	12	15	4	4.2	0.0	0.0
Des Moines	861	84	97	29.10	29.99	+ .03	73.8	− 1.7	93	23	84	55	27	64	28	66	61	67	5.66	+ 1.8	12	3,998	sw.	31	sw.	1	17	9	5	....	0.0	0.0
Dubuque	698	81	96	29.43	30.02	+ .05	71.2	− 3.5	92	23	81	52	5	62	28	64	59	67	1.11	− 3.2	8	4,163	nw.	31	n.	9	14	11	6	4.3	0.0	0.0
Keokuk	614	64	78	29.35	30.02	+ .05	75.3	− 1.7	97	23	85	57	7	66	28	66	62	64	3.84	− 0.2	8	4,163	sw.	50	nw.	1	9	17	5	4.8	0.0	0.0
Cairo	356	87	93	29.63	30.00	.00	78.3	− 0.3	94	24	87	60	27	69	24	70	66	72	2.82	− 0.6	8	4,637	sw.	48	nw.	14	11	13	7	4.9	0.0	0.0
Peoria	609	11	45	29.35	30.01	+ .01	73.6	− 1.8	98	23	86	53	25	62	35	65	62	66	1.56	− 1.4	10	3,623	w.	20	sw.	1	21	9	1	2.6	0.0	0.0
Springfield, Ill.	644	10	91	29.32	29.98	......	76.2	− 0.3	100	23	88	55	25	65	30	65	59	61	0.92	− 2.0	8	5,149	w.	29	w.	7	10	14	7	4.9	0.0	0.0
Hannibal	534	74	109	29.44	30.00	+ .02	75.3	− 2.1	98	23	86	56	27	64	32	....	....	....	2.74	− 1.0	10	4,900	sw.	37	sw.	12	14	10	7	4.3	0.0	0.0
St. Louis	567	265	303	29.40	30.00	+ .01	78.8	− 0.3	99	23	88	61	25	69	24	67	60	56	0.73	− 2.7	9	7,538	sw.	50	sw.	1	16	14	1	3.3	0.0	0.0
Missouri Valley.							**75.1**	**− 0.5**										**68**	**3.73**	**0.0**										**3.9**		
Columbia, Mo.	781	11	84	29.19	30.00	+ .02	75.8	− 1.6	98	23	87	57	26	65	30	....	....	....	2.61	− 1.0	9	4,449	sw.	33	s.	12	16	10	5	3.9	0.0	0.0
Kansas City	963	161	181	28.99	30.00	+ .03	76.8	− 0.8	98	23	86	58	26	68	26	67	62	65	9.78	+ 4.9	10	6,518	sw.	55	nw.	1	19	9	3	3.3	0.0	0.0
St. Joseph	967	11	49	28.98	29.99	......	76.7	......	100	23	87	57	27	66	26	67	63	67	3.34	......	12	4,652	sw.	38	nw.	6	17	13	1	3.3	0.0	0.0
Springfield, Mo.	1,324	98	104	28.64	30.02	+ .04	76.0	− 0.4	95	4	85	57	9	67	29	68	64	71	2.42	− 2.4	9	5,277	s.	38	s.	3	15	12	4	3.8	0.0	0.0
Iola	984	11	50	28.97	29.98	+ .01	77.7	− 0.4	99	4	89	56	9	66	31	....	....	....	4.13	+ 0.2	9	3,258	s.	24	ne.	26	14	13	4	4.3	0.0	0.0
Topeka	987	92	107	......	......	......	76.8	......	99	3	88	56	10	66	28	....	....	....	6.63	+ 1.8	7	5,850	sw.	50	n.	14	15	11	5	3.8	0.0	0.0
Drexel	1,299	10	53	28.62	29.98	......	73.5	......	96	21	84	51	8	62	29	66	63	71	5.18	......	11	5,709	s.	31	s.	3	18	11	2	3.5	0.0	0.0
Lincoln	1,189	11	84	28.75	29.98	+ .03	76.6	+ 0.2	99	22	88	54	8	65	31	66	60	66	3.80	0.0	10	5,626	s.	46	n.	13	14	14	3	3.8	0.0	0.0
Omaha	1,105	115	122	28.84	29.99	+ .04	76.4	− 0.1	98	21	86	56	8	67	27	67	62	64	3.91	− 0.4	9	4,565	s.	39	nw.	3	14	14	3	3.8	0.0	0.0
Valentine	2,598	47	54	27.34	30.00	+ .07	73.4	+ 0.2	102	21	87	48	8	60	38	62	56	61	1.14	− 2.3	10	6,471	e.	63	sw.	3	16	12	3	3.9	0.0	0.0
Sioux City	1,135	94	164	28.81	29.99	+ .04	74.4	+ 0.2	98	22	84	55	8	65	27	66	62	70	3.89	+ 0.3	13	6,670	s.	57	w.	4	13	9	9	4.6	0.0	0.0
Huron	1,306	59	74	28.63	30.00	+ .06	71.4	− 0.1	96	23	81	54	14	61	28	65	61	73	5.39	+ 2.4	9	5,990	se.	33	n.	3	18	9	4	3.3	0.0	0.0
Pierre	1,572	70	75	28.34	29.98	+ .07	73.1	− 2.1	105	22	84	52	14	62	32	65	62	71	2.81	+ 0.5	10	5,217	e.	42	nw.	13	18	5	8	4.1	0.0	0.0
Yankton	1,233	49	57	28.68	29.97	+ .03	74.2	− 0.4	100	22	85	54	14	64	29	....	....	....	1.34	− 2.2	11	4,540	sw.	26	nw.	1	11	18	2	4.8	0.0	0.0

TABLE I.—*Climatological data for Weather Bureau Stations, July, 1920*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.												Precipitation.			Wind.										
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sealevel, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, ice, and sleet on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.		In.	In.		Miles.								0–10	In.	In.
Northern Slope.							**69.1**	**+ 1.6**										**56**	**1.14**	**- 0.5**										**3.6**		
Billings	3,140	5																														
Havre	2,505	11	44	27.40	29.98	+ .07	72.4	+ 4.3	97	18	87	43	7	58	36	60	53	59	1.51	- 0.4	7	4,344	e.	32	n.	12	27	2	2	2.5	0.0	0.0
Helena	4,110	87	112	25.88	29.99	+ .06	69.4	+ 2.8	96	21	83	44	7	55	36	54	44	48	0.76	- 0.3	10	5,497	sw.	37	sw.	19	12	15	4	4.2	0.0	0.0
Kalispell	2,973	48	56	26.95	29.93	.00	69.6	+ 5.3	95	15	86	43	7	54	40	54	43	47	0.98	+ 0.1	7	4,306	nw.	34	se.	19	25	5	1	2.7	0.0	0.0
Miles City	2,371	26	48																													
Rapid City	3,259	50	58	26.69	30.04	+ .11	70.6	+ 0.4	101	22	82	50	8	59	33	60	54	60	1.46	- 1.1	7	4,683	w.	39	n.	13	15	11	5	4.5	0.0	0.0
Cheyenne	6,088	84	101	24.17	30.01	+ .09	65.8	- 1.6	91	22	79	44	7	53	35	54	47	57	2.12	+ 0.1	15	6,428	w.	40	ne.	6	12	17	2	4.3	0.0	0.0
Lander	5,372	60	68	24.78	30.01	+ .09	68.2	+ 0.2	97	21	84	40	7	52	43	54	45	49	0.05	- 0.8	2	3,734	sw.	38	w.	21	11	18	2	4.4	0.0	0.0
Sheridan	3,790	10	47	26.19	30.02		68.6		95	27	84	37	8	53	47	58	52	61	1.51		9	3,111	s.	37	nw.	4	18	8	5	3.5	0.0	0.0
Yellowstone Park	6,200	11	48	24.04	30.04	+ .12	62.2	+ 0.7	86	21	77	36	7	47	38	50	42	57	0.65	- 0.5	13	4,904	s.	29	sw.	12	10	18	3	4.3	0.0	0.0
North Platte	2,821	11	51	27.16	30.02	+ .09	74.8	+ 0.9	99	22	88	50	8	51	38	63	57	63	1.62	- 1.1	12	4,338	s.	30	w.	1	26	4	1	2.1	0.0	0.0
Middle Slope.							**76.7**	**0.0**										**60**	**3.14**	**+ 0.2**										**4.0**		
Denver	5,292	106	113	24.87	30.02	+ .10	72.2	+ 0.4	94	22	84	52	7	60	30	57	47	48	0.45	- 1.2	4	5,054	s.	32	n.	25	12	18	1	4.1	0.0	0.0
Pueblo	4,685	80	86	25.40	29.99	+ .08	74.4	+ 0.2	98	13	88	53	13	61	45	58	50	52	1.62	- 0.4	8	4,910	se.	38	nw.	24	9	18	4	5.0	0.0	0.0
Concordia	1,392	50	58	28.55	29.99	+ .04	77.4	- 0.7	104	23	89	56	8	65	39	66	60	60	4.90	+ 1.3	6	5,002	s.	36	nw.	5	13	16	2	4.1	0.0	0.0
Dodge City	2,509	11	51	27.46	29.99	+ .06	77.9	+ 0.2	100	23	91	56	10	65	35	65	60	61	3.79	+ 0.4	7	6,525	se.	34	n.	5	18	13	0	2.6	0.0	0.0
Wichita	1,358	139	158	28.59	29.98	+ .02	78.5	- 0.5	100	3	88	60	10	68	27	69	64	68	4.05	+ 0.4	12	7,769	s.	44	w.	16	17	11	3	3.5	0.0	0.0
Altus	1,410	5					82.6		105	2	96	62	9	70	35				3.66		5		se.				16	5	10		0.0	0.0
Broken Arrow	765	11	52																													
Muskogee	652	4					80.4		100	2	92	61	10	68	35				3.53		6		e.				12	14	5		0.0	0.0
Oklahoma	1,214	10	47	28.74	29.98	+ .02	80.0	+ 0.2	100	3	91	63	9	70	27	70	66	68	4.02	+ 0.4	7	6,985	s.	33	n.	16	11	15	5	4.6	0.0	0.0
Southern Slope.							**81.1**	**+ 0.6**										**55**	**1.46**	**- 1.4**										**3.6**		
Abilene	1,738	10	52	28.20	29.95	+ .02	83.6	+ 1.4	102	17	96	65	7	72	31	69	62	57	1.81	- 0.6	3	6,100	s.	30	se.	11	13	13	5	4.2	0.0	0.0
Amarillo	3,676	10	49	26.34	29.98	+ .06	78.1	+ 2.0	98	3	92	59	28	65	32	64	57	57	1.85	- 1.3	8	6,854	s.	33	w.	11	14	16	1	4.0	0.0	0.0
Del Rio	944	64	71	28.99	29.95	+ .05	84.7	0.0	100	5	95	68	27	74	27				1.38	- 0.9	4	7,457	se.	35	se.	4	19	7	5	3.5	0.0	0.0
Roswell	3,566	75	85	26.41	29.93	+ .05	78.1	- 0.8	101	13	92	60	10	64	35	62	54	52	0.81	- 2.6	6	5,271	s.	37	sw.	23	18	13	0	2.9	0.0	0.0
Southern Plateau.							**82.4**	**+ 0.6**										**37**	**0.43**	**- 0.8**										**2.4**		
El Paso	3,762	110	133	26.21	29.86	+ .02	82.6	+ 2.1	100	5	94	58	20	71	33	63	50	40	0.84	- 1.3	7	7,932	e.	57	ne.	8	23	8	0	2.5	0.0	0.0
Santa Fe	7,013	57	66	23.40	29.91	+ .03	68.7	0.0	85	7	81	51	19	56	30	53	42	45	1.04	- 1.7	8	5,025	e.	30	se.	8	8	18	5	4.8	0.0	0.0
Flagstaff	6,908	8	57																													
Phoenix	1,108	76	81	28.68	29.79	+ .01	90.6	+ 0.2	114	8	106	65	1	75	43	67	53	35	0.25	- 0.8	3	3,913	w.	37	s.	13	22	9	0	1.8	0.0	0.0
Yuma	141	9	54	29.69	29.80	+ .04	92.8	+ 1.9	116	8	108	68	1	77	40	71	60	40	T	- 0.1	0	3,826	sw.	22	s.	20	30	1	0	1.0	0.0	0.0
Independence	3,957	9	41	25.98	29.93	+ .10	77.4	- 1.1	100	6	94	54	13	61	39	54	33	24	T	- 0.1	0	4,817	s.	29	se.	14	25	5	1	2.0	0.0	0.0
Middle Plateau.							**73.1**	**+ 0.3**										**33**	**0.46**	**0.0**										**2.6**		
Reno	4,532	74	81	25.51	29.93	+ .06	69.0	+ 1.5	94	8	87	44	14	51	46	50	36	38	T.	- 0.1	0	5,682	w.	36	w.	2	26	5	0	1.3	0.0	0.0
Tonopah	6,090	12	20	24.14	29.92		73.4		93	6	86	50	4	61	31	50	28	22	0.24	- 0.1	1	6,628	se.	29	e.	22	18	13	0	2.6	0.0	0.0
Winnemucca	4,344	18	56	25.64	29.95	+ .05	70.6	- 1.0	96	27	90	44	5	52	47	50	33	32	T.	- 0.2	0	4,591	sw.	26	se.	15	25	6	0	1.5	0.0	0.0
Modena	5,479	10	43	24.70	29.93	+ .07	69.8	+ 0.1	93	7	87	42	4	52	45	51	35	38	1.82	+ 0.6	7	7,945	w.	44	w.	14	21	8	2	2.8	0.0	0.0
Salt Lake City	4,360	163	203	25.65	29.92	+ .02	78.6	+ 2.4	98	21	90	59	1	67	29	57	42	31	0.51	0.0	3	5,591	se.	36	se.	11	17	9	5	3.5	0.0	0.0
Grand Junction	4,602	60	68	25.44	29.96	+ .07	77.7	- 1.5	99	20	92	55	5	63	35	57	44	36	0.17	- 0.3	3	4,679	se.	34	se.	21	12	15	4	4.1	0.0	0.0
Northern Plateau.							**74.1**	**+ 3.2**										**40**	**0.35**	**- 0.1**										**3.0**		
Baker	3,471	48	53	26.46	29.98	+ .03	68.4	+ 3.4	96	28	85	41	14	52	44	53	42	47	0.32	- 0.1	4	4,307	se.	34	se.	3	19	9	3	2.9	0.0	0.0
Boise	2,739	78	86	27.12	29.91	- .02	76.2	+ 3.4	99	2	92	52	13	60	40	59	48	42	0.05	- 0.1	2	3,706	nw.	22	e.	27	23	7	1	2.2	0.0	0.0
Lewiston	757	40	48	29.15	29.94	- .01	76.5	+ 2.9	106	27	93	53	14	60	47				0.63	+ 0.2	5	2,441	e.	24	nw.	13	19	8	4	3.0	0.0	0.0
Pocatello	4,477	60	68	25.52	29.93	+ .01	72.6	+ 1.4	96	21	88	46	7	57	41	54	40	37	0.33	- 0.3	8	5,914	se.	33	s.	11	10	19	2	4.4	0.0	0.0
Spokane	1,929	101	110	27.95	29.95	- .01	74.2	+ 5.4	101	28	88	51	26	60	41	57	44	40	0.66	0.0	2	4,891	sw.	31	s.	13	24	5	2	2.9	0.0	0.0
Walla Walla	991	57	65	28.90	29.95	- .02	76.5	+ 2.4	104	27	90	50	13	63	41	58	43	36	0.13	- 0.3	4	3,594	s.	27	sw.	16	22	7	2	2.4	0.0	0.0
North Pacific Coast Region.							**62.8**	**+ 0.7**										**75**	**0.85**	**+ 0.1**										**4.8**		
North Head	211	11	56	29.88	30.11	+ .03	57.0	- 0.7	66	13	60	50	7	54	15	55	53	86	0.89	+ 0.4	8	8,806	nw.	38	nw.	1	4	17	10	6.2	0.0	0.0
Port Angeles	29	8	53	30.08	30.11		58.2		83	15	67	42	6	50	34				0.68	+ 0.3	5	4,925	nw.	19	nw.	28	15	10	6	4.2	0.0	0.0
Seattle	125	215	250	29.95	30.08	+ .04	64.2	+ 0.6	89	7	74	49	5	55	29	57	52	71	1.00	+ 0.3	4	5,364	n.	27	sw.	29	12	11	8	4.7	0.0	0.0
Tacoma	213	113	120	29.85	30.07	+ .01	64.6	+ 1.2	90	7	75	48	5	54	32	58	53	72	0.83	+ 0.2	4	3,989	n.	18	w.	8	10	12	9	5.3	0.0	0.0
Tatoosh Island	86	7	57	30.00	30.09	+ .04	55.0	- 0.1	70	7	59	48	6	51	20	53	53	94	0.76	- 1.0	9	7,387	s.	37	s.	4	7	12	12	5.6	0.0	0.0
Yakima	1,071	4					74.8		100	28	91	50	13	58	41				0.25		2						21	6	4		0.0	0.0
Medford	1,425	4																														
Portland, Oreg.	153	68	106	29.90	30.06	+ .01	68.0	+ 1.7	97	7	79	50	4	57	33	59	53	64	1.18	+ 0.6	4	3,920	nw.	24	w.	21	12	14	5	4.2	0.0	0.0
Roseburg	510	9	57	29.52	30.06	+ .03	67.8	+ 1.7	94	7	82	45	4	53	44	57	49	61	0.42	+ 0.1	2	2,646	n.	14	nw.	16	18	11	2	2.6	0.0	0.0
Middle Pacific Coast Region.							**63.9**	**- 1.6**										**63**	**0.02**	**0.0**										**3.4**		
Eureka	62	73	89	30.05	30.12	+ .07	56.9	+ 1.6	66	29	61	49	7	53	14	54	52	86	0.13	0.0	4	4,420	n.	19	n.	24	5	15	11	6.4	0.0	0.0
Mount Tamalpais	2,375	11	18	27.58	30.02	+ .07	65.2	- 5.3	87	6	73	45	14	57	28	53	43	49	0.00	0.0	0	13,482	nw.	80	nw.	12	25	5	1	1.5	0.0	0.0
Point Reyes Light	490	7	18	29.49	30.01		52.9	- 0.8	65	3	57	46	11	49	13				0.07		2	21,050	nw.	72	nw.	12	0	13	18	7.6	0.0	0.0
Red Bluff	332	50	56	29.58	29.92	+ .03	78.2	- 3.9	107	7	94	53	14	63	38	60	46	39	0.01	0.0	1	3,876	se.	22	nw.	11	30	1	0	0.6	0.0	0.0
Sacramento	69	106	117	29.88	29.95	+ .07	71.6	- 0.9	102	6	88	51	10	55	44	58	50	56	0.00	0.0	0	6,577	s.	27	s.	2	30	1	0	1.1	0.0	0.0
San Francisco	155	208	243	29.85	30.02	+ .07	57.8	+ 0.5	72	22	64	48	10	52	20	54	52	86	T.	0.0	0	11,252	sw.	40	w.	19	10	14	7	4.5	0.0	0.0
San Jose	141	12	110	29.88	30.03		64.4	- 2.5	89	22	77	47	22	51	42				0.00	0.0	0	4,541	nw.	23	sw.	2	28	3	0	1.8	0.0	0.0
South Pacific Coast Region.							**70.4**	**- 0.2**										**62**	**T.**	**0.0**										**1.7**		
Fresno	327	89	98	29.58	29.92	+ .09	79.4	- 2.6	107	7	96	55	14	62	39	58	41	33	0.00	0.0	0	6,856	nw.	26	nw.	2	30	1	0	0.3	0.0	0.0
Los Angeles	338	159	191	29.59	29.95	+ .05	71.2	+ 0.8	90	30	82	54	9	61	30	61	56	68	T.	0.0	0	3,951	sw.	18	s.	15	24	7	0	1.9	0.0	0.0
San Diego	87	62	70	29.85	29.94	+ .02	67.0	+ 0.1	78	17	72	58	4	62	15	62	60	81	T.	0.0	0	4,779	nw.	24	s.	30	22	8	1	3.1	0.0	0.0
San Luis Obispo	201	32	40	29.79	30.01	+ .06	64.0	+ 0.8	89	29	77	45	12	51	38	55	49	68	T.	0.0	0	3,277	nw.	19	ne.	30	28	2	1	1.6	0.0	0.0
West Indies.																																
San Juan, P. R.	82	8	54	29.99	30.08		79.4		85	27	83	72	10	76	11				3.87	- 2.6	21	13,695	e.	40	e.	18	5	19	7	5.5	0.0	0.0
Panama Canal.																																
Balboa Heights	118	7	97	29.72	29.84	+ .01	80.7	+ 0.4	93	12	87	71	7	75	18	75	74	86	6.18	- 1.4	19	4,398	nw.	26	n.	31	0	10	21	8.2	0.0	0.0
Colon	36	7	97	29.82	29.86	.00	81.1	+ 1.1	88	11	86	73	5	76	14	77	76	86	17.58	+ 1.6	23	7,030	w.	31	ne.	17	0	2	29	9.0	0.0	0.0
Alaska.																																
Juneau	80	11	49																													

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during July, 1920, at all stations furnished with self-registering gages.*

Stations.	Date.	Total duration. From—	Total duration. To—	Total amount of precipitation.	Excessive rate. Began—	Excessive rate. Ended—	Amount before excessive rate began.	5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Abilene, Tex	19	1:40 p. m.	2:45 p. m.	1.21	1:47 p. m.	2:13 p. m.	0.01	0.14	0.32	0.64	0.95	1.12	1.15								
Albany, N. Y	19			0.70														0.52			
Alpena, Mich.*	18			0.50														0.34			
Amarillo, Tex	26			0.49														0.38			
Anniston, Ala	7			0.67														0.52			
Asheville, N. C	17	1:30 p. m.	2:50 p. m.	0.54	2:20 p. m.	2:43 p. m.	0.02	0.06	0.23	0.34	0.45	0.52									
Atlanta, Ga	10	2:47 p. m.	5:44 p. m.	1.46	2:49 p. m.	3:35 p. m.	0.01	0.08	0.34	0.51	0.69	0.87	1.02	1.13	1.19	1.28	1.29				
	11	9:50 p. m.	D. N. p. m.	1.05	10:23 p. m.	10:56 p. m.	0.16	0.05	0.19	0.24	0.31	0.52	0.72	0.83							
	18	11:48 a. m.	4:00 p. m.	1.30	12:41 p. m.	1:14 p. m.	0.14	0.22	0.61	0.80	0.85	0.87	1.07	1.14							
Atlantic City, N. J	18			0.71														0.38			
Augusta, Ga	15	3:45 p. m.	6:00 p. m.	0.94	4:03 p. m.	4:23 p. m.	0.01	0.16	0.46	0.62	0.73										
	18	8:30 p. m.	9:30 p. m.	0.72	8:37 p. m.	8:53 p. m.	0.04	0.17	0.39	0.62	0.67										
	21	11:15 a. m.	6:00 p. m.	1.88	12 noon.	12:47 p. m.	0.04	0.06	0.21	0.47	0.76	0.99	1.19	1.33	1.44	1.52	1.57				
Baker, Oreg	11			0.19														0.18			
Baltimore, Md	2	4:25 p. m.	8:25 p. m.	1.90	5:25 p. m.	5:49 p. m.	0.06	0.24	0.43	0.53	0.60	0.69									
					7:38 p. m.	8:06 p. m.	0.98	0.05	0.23	0.36	0.51	0.81	0.88								
	7	4:22 p. m.	6:25 p. m.	0.71	4:22 p. m.	4:36 p. m.	0.00	0.13	0.40	0.54											
	19	12:17 p. m.	1:10 p. m.	0.61	12:24 p. m.	12:42 p. m.	0.02	0.28	0.43	0.50	0.57										
Bentonville, Ark	16	8:50 a. m.	2:20 p. m.	2.14	9:37 a. m.	10:45 a. m.	0.03	0.16	0.35	0.50	0.72	0.85	0.85	0.98	1.11	1.27	1.39	1.52	1.71		
Binghamton, N. Y	18	9:00 p. m.	10:40 p. m.	0.96	9:23 p. m.	10:13 p. m.	0.13	0.08	0.19	0.25	0.36	0.42	0.47	0.53	0.57	0.66	0.79				
	22	5:10 p. m.	11:00 p. m.	1.25	5:19 p. m.	5:59 p. m.	0.01	0.06	0.19	0.33	0.53	0.62	0.70	0.80	0.91						
	23–24	9:25 p. m.	D. N. a. m.	1.65	10:53 p. m.	11:20 p. m.	0.05	0.28	0.45	0.75	1.14	1.28	1.34								
Birmingham, Ala	6–7	11:30 p. m.	6:30 a. m.	0.87	11:43 p. m.	11:58 p. m.	0.01	0.26	0.43	0.57											
	10	10:50 a. m.	12:24 p. m.	0.66	10:53 a. m.	11:04 a. m.	0.01	0.31	0.51	0.52											
	13	4:59 p. m.	6:05 p. m.	0.64	5:00 p. m.	5:26 p. m.	0.01	0.18	0.31	0.40	0.49	0.57	0.60								
Bismarck, N. Dak	13	D. N. a. m.	D. N. a. m.	1.20	2:15 a. m.	2:37 a. m.	0.27	0.09	0.27	0.43	0.52	0.56									
Block Island, R. I	15	1:02 p. m.	3:00 p. m.	1.33	2:40 p. m.	2:53 p. m.	0.78	0.25	0.52	0.55											
Boise, Idaho	29			0.04														0.04			
Boston, Mass	3			0.76														0.22			
Buffalo, N. Y	23–24	6:30 p. m.	D. N. a. m.	2.58	7:32 p. m.	9:09 p. m.	0.10	0.08	0.23	0.43	0.51	0.59	0.81	0.93	1.05	1.08	1.13	1.18	1.39	2.33	
Burlington, Vt	12	5:37 p. m.	7:25 p. m.	0.85	5:42 p. m.	6:06 p. m.	0.02	0.23	0.37	0.50	0.61	0.70									
Cairo, Ill	19	12:10 a. m.	D. N. a. m.	1.23	12:23 a. m.	12:52 a. m.	0.02	0.06	0.15	0.26	0.44	0.62	0.71								
Canton, N. Y	2–3			1.10														0.49			
Charles City, Iowa	5	12:35 a. m.	8:36 a. m.	0.81	12:43 a. m.	12:58 a. m.	0.04	0.16	0.41	0.53											
Charleston, S. C	8	1:53 p. m.	4:20 p. m.	0.76	1:57 p. m.	2:13 p. m.	0.01	0.21	0.35	0.59	0.63										
	9	4:29 p. m.	9:20 p. m.	1.19	4:37 p. m.	5:09 p. m.	0.01	0.13	0.38	0.78	0.86	0.87	0.94	0.98							
Charlotte, N. C	14			0.63														0.61			
Chattanooga, Tenn	7	3:26 p. m.	3:44 p. m.	0.61	3:31 p. m.	3:39 p. m.	T.	0.40	0.60												
	21	1:28 p. m.	2:21 p. m.	0.54	1:37 p. m.	2:04 p. m.	T.	0.16	0.28	0.34	0.43	0.47	0.53								
Cheyenne, Wyo	8			0.36														0.36			
Chicago, Ill	13	5:53 p. m.	8:30 p. m.	0.85	6:41 p. m.	7:08 p. m.	0.23	0.13	0.18	0.25	0.34	0.50	0.54								
Cincinnati, Ohio	6			1.19														0.52			
Cleveland, Ohio	2	9:05 p. m.	10:10 p. m.	1.04	9:27 p. m.	9:58 p. m.	0.17	0.17	0.27	0.31	0.34	0.66	0.85	0.87							
	18	1:29 p. m.	5:07 p. m.	0.99	1:54 p. m.	2:19 p. m.	0.12	0.11	0.39	0.52	0.60	0.78									
Columbia, Mo	31	8:44 a. m.	10:21 a. m.	1.47	8:48 a. m.	9:40 a. m.	0.01	0.17	0.24	0.24	0.40	0.68	0.85	0.98	1.10	1.30	1.42	1.44			
Columbia, S. C	15	2:43 p. m.	5:45 p. m.	0.66	3:34 p. m.	3:54 p. m.	0.03	0.06	0.27	0.47	0.57										
Columbus, Ohio	2	D. N. a. m.	8:55 a. m.	1.11	7:06 a. m.	7:48 a. m.	0.26	0.07	0.11	0.26	0.37	0.54	0.60	0.66	0.71	0.76					
	6	1:30 p. m.	8:45 p. m.	1.05	5:04 p. m.	5:26 p. m.	0.13	0.18	0.37	0.52	0.63	0.66									
Concord, N. H	19	5:20 p. m.	5:55 p. m.	0.59	5:27 p. m.	5:40 p. m.	0.02	0.14	0.35	0.5[illegible]											
Concordia, Kans	5	2:30 a. m.	5:18 a. m.	0.95	2:38 a. m.	3:08 a. m.	0.01	0.08	0.20	0.2[illegible]	0.30	0.49	0.73								
Corpus Christi, Tex	31			0.15														0.10			
Dallas, Tex	18			0.73														0.45			
Davenport, Iowa	5			0.95														0.33			
Dayton, Ohio	2	5:41 a. m.	10:25 a. m.	0.89	6:03 a. m.	6:43 a. m.	0.15	0.12	0.24	0.29	0.25	0.38	0.44	0.58	0.66						
Del Rio, Tex	6			0.51														0.50			
Denver, Colo	25			0.22														0.14			
Des Moines, Iowa	5			1.32														0.73			
Detroit, Mich	8	3:40 p. m.	5:15 p. m.	1.11	3:44 p. m.	4:07 p. m.	0.02	0.24	0.52	0.75	0.93	1.01									
Devils Lake, N. Dak	16	4:40 p. m.	5:15 p. m.	1.10	4:54 p. m.	5:11 p. m.	0.06	0.18	0.60	1.01	1.04										
Dodge City, Kans	9	D. N. a. m.	7:15 a. m.	1.73	2:17 a. m.	2:47 a. m.	0.01	0.16	0.57	0.87	1.11	1.26	1.33								
Drexel, Nebr	1	1:25 a. m.	3:10 a. m.	0.85	1:28 a. m.	2:03 a. m.	0.01	0.11	0.31	0.49	0.61	0.71	0.76	0.82							
	5	10:44 a. m.	1:50 p. m.	1.13	11:47 a. m.	12:22 p. m.	0.10	0.17	0.37	0.48	0.60	0.75	0.78	0.84							
Dubuque, Iowa	5			0.71														0.18			
Duluth, Minn	17	5:15 p. m.	5:42 p. m.	0.58	5:23 p. m.	5:33 p. m.	0.04	0.26	0.52												
Eastport, Me	23			0.44														0.18			
Elkins, W. Va	3	3:20 p. m.	5:36 p. m.	1.22	3:42 p. m.	4:31 p. m.	0.04	0.20	0.47	0.57	0.57	0.60	0.86	0.96	0.99	1.03	1.11				
Ellendale, N. Dak	13	D. N. a. m.	D. N. a. m.	0.84	3:42 a. m.	4:12 a. m.	0.01	0.06	0.13	0.41	0.55	0.67	0.72								
El Paso, Tex	19–20			0.52														0.52			
Erie, Pa	18			2.03														0.66			
Escanaba, Mich	1			0.53														0.39			
Eureka, Calif	14			0.08														0.07			
Evansville, Ind	6	1:20 p. m.	2:26 p. m.	0.76	1:29 p. m.	1:55 p. m.	0.01	0.12	0.24	0.30	0.39	0.62	0.74								
Flagstaff, Ariz	28–29			0.47																	
Fort Smith, Ark	16	10:55 a. m.	3:20 p. m.	0.93	11:17 a. m.	11:45 a. m.	0.03	0.11	0.20	0.29	0.43	0.54	0.59								
Fort Wayne, Ind	6	1:30 p. m.	6:28 p. m.	1.74	3:42 p. m.	4:17 p. m.	0.67	0.21	0.45	0.54	0.60	0.72	0.85	0.97							
	18	12:27 p. m.	1:35 p. m.	0.77	12:32 p. m.	1:19 p. m.	0.01	0.08	0.26	0.41	0.45	0.49	0.51	0.52	0.60	0.72	0.76				
	30	3:14 p. m.	6:00 p. m.	1.75	3:21 p. m.	4:33 p. m.	0.01	0.23	0.34	0.36	0.52	0.55	0.55	0.55	0.60	0.69	0.94	1.05	1.29		
Fort Worth, Tex	6	12:18 a. m.	D. N. a. m.	0.65	12:29 a. m.	12:52 a. m.	0.01	0.07	0.12	0.26	0.45	0.53									
	18	2:34 a. m.	5:39 a. m.	0.91	4:31 a. m.	5:02 a. m.	0.05	0.06	0.26	0.33	0.44	0.61	0.76	0.80							
	20	12:51 p. m.	4:30 p. m.	1.10	1:00 p. m.	1:19 p. m.	0.02	0.50	0.74	0.90	0.98										
Fresno, Calif	(‡)			(‡)																	
Galveston, Tex	15	6:53 a. m.	8:35 a. m.	0.70	6:58 a. m.	7:12 a. m.	0.01	0.26	0.53	0.68											
Grand Haven, Mich	31			0.18														0.17			
Grand Junction, Colo	25			0.09														0.08			
Grand Rapids, Mich	6	6:25 p. m.	8:30 p. m.	0.86	7:39 p. m.	8:07 p. m.	0.11	0.05	0.15	0.32	0.53	0.65	0.74								
	18	D. N. a. m.	5:30 a. m.	1.12	4:48 a. m.	5:16 a. m.	0.32	0.16	0.32	0.47	0.59	0.72	0.77								
Green Bay, Wis	17–18	10:45 p. m.	D. N. a. m.	0.57	10:59 p. m.	11:19 p. m.	0.95	0.07	0.13	0.28	0.50										
Greenville, S. C	2	4:10 p. m.	6:30 p. m.	0.90	4:20 p. m.	4:38 p. m.	0.02	0.12	0.30	0.56	0.74										
	16	2:28 p. m.	4:05 p. m.	0.93	2:41 p. m.	3:07 p. m.	0.06	0.07	0.20	0.32	0.61	0.82	0.83								
		7:05 p. m.	8:45 p. m.	0.72	7:38 p. m.	8:18 p. m.	0.05	0.20	0.33	0.36	0.39	0.43	0.52	0.61	0.66						
	18	9:38 a. m.	12 noon.	1.41	10:58 a. m.	11:29 a. m.	0.08	0.29	0.73	0.89	1.05	1.14	1.25	1.28							
	20	8:28 p. m.	10:30 p. m.	1.72	8:32 p. m.	9:07 p. m.	0.02	0.15	0.45	0.73	1.01	1.25	1.49	1.56							
Hannibal, Mo	1	10:05 p. m.	11:05 p. m.	0.66	10:24 p. m.	10:37 p. m.	0.06	0.19	0.49	0.58											
Harrisburg, Pa	11–12	8:20 p. m.	D. N. a. m.	1.35	10:04 p. m.	10:45 p. m.	0.13	0.13	0.21	0.30	0.38	0.52	0.61	0.68	0.74	0.77					
	14	2:50 p. m.	3:30 p. m.	0.65	2:50 p. m.	3:10 p. m.	0.00	0.17	0.41	0.59	0.64										
	31	4:52 p. m.	6:10 p. m.	0.56	5:13 p. m.	5:39 p. m.	0.01	0.12	0.21	0.23	0.40	0.52	0.54								
Hartford, Conn	12	D. N. a. m.	9:40 a. m.	1.23	6:18 a. m.	6:33 a. m.	0.12	0.11	0.43	0.51											
		3:54 p. m.	4:50 p. m.	1.18	4:17 p. m.	4:44 p. m.	0.01	0.23	0.46	0.74	0.96	1.11	1.17								
	15	2:50 p. m.	5:35 p. m.	0.93	4:28 p. m.	4:53 p. m.	0.07	0.10	0.30	0.56	0.77	0.84									

* Self-register not in use. † Record partly estimated. ‡ No precipitation occurred during month.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during July, 1920, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Hatteras, N. C.	9	12 noon.	D. N. p. m.	1.34	12:35 p. m.	1:16 p. m.	0.10	0.16	0.27	0.44	0.51	0.61	0.77	0.84	0.91	0.94					
Havre, Mont.	12			0.82														0.53			
Helena, Mont.	12			0.39														0.38			
Houghton, Mich.	17			1.07														0.29			
Houston, Tex.	2	2:04 p. m.	2:58 p. m.	1.03	2:04 p. m.	2:40 p. m.	0.00	0.20	0.55	0.65	0.70	0.82	0.89	0.98	1.01						
	13	10:28 a. m.	11:21 a. m.	0.80	10:35 a. m.	10:46 a. m.	0.01	0.30	0.59	0.60											
	22	6:45 p. m.	7:50 p. m.	1.10	6:47 p. m.	7:14 p. m.	0.01	0.18	0.28	0.54	0.79	0.98	1.02								
Huron, S. Dak.	4	3:20 p. m.	5:30 p. m.	1.62	3:47 p. m.	4:17 p. m.	0.05	0.07	0.14	0.33	0.67	1.03	1.26								
	7	10:54 a. m.	1:17 p. m.	1.28	12:21 p. m.	12:31 p. m.	0.38	0.34	0.74												
Independence, Calif.	16			T.														T.			
Indianapolis, Ind.	3	12:29 p. m.	1:28 p. m.	0.90	12:44 p. m.	1:04 p. m.	0.03	0.08	0.30	0.54	0.79										
	13–14	9:53 p. m.	5:27 a. m.	1.54	2:58 a. m.	3:21 a. m.	0.35	0.19	0.52	0.77	0.83	0.88									
Iola, Kans.	16	6:42 a. m.	11:20 a. m.	1.80	7;52 a. m.	8:22 a. m.	0.18	0.14	0.53	0.80	1.04	1.17	1.26								
Jacksonville, Fla.	22	11:32 a. m.	2:09 p. m.	0.97	1:01 p. m.	1:42 p. m.	0.27	0.07	0.27	0.35	0.35	0.35	0.39	0.62	0.68	0.69					
Kalispell, Mont.	21			0.31														0.27			
Kansas City, Mo.	1	7:30 p. m.	8:45 p. m.	1.01	7:42 p. m.	8:09 p. m.	0.02	0.16	0.39	0.59	0.75	0.89	0.95								
	12–13	9:50 p. m.	6:00 a. m.	1.98	1:35 a. m.	2:18 a. m.	0.85	0.21	0.24	0.30	0.32	0.40	0.43	0.50	0.62	0.70					
	25	3:55 a. m.	8:55 a. m.	3.56	4:06 a. m.	5:43 a. m.	0.01	0.08	0.21	0.49	0.72	0.80	0.93	1.12	1.25	1.48	1.66	2.03	2.53	3.08	
	31	6:00 p. m.	D. N. p. m.	1.10	6:54 p. m.	7:13 p. m.	0.12	0.11	0.20	0.46	0.55										
Keokuk, Iowa	5	6:15 p. m.	10:58 p. m.	0.97	8:56 p. m.	9:26 p. m.	0.05	0.06	0.33	0.53	0.65	0.73	0.79								
Key West, Fla.	16			0.29														0.29			
Knoxville, Tenn.	25			0.50														0.50			
Lander, Wyo.	16			0.03														0.03			
Lansing, Mich.	18	5:15 a. m.	7:45 a. m.	1.39	5:23 a. m.	6:36 a. m.	0.02	0.15	0.31	0.38	0.41	0.45	0.57	0.65	0.74	0.79	0.90	1.07	1.28		
Lewiston, Idaho	21			0.18														0.18			
Lexington, Ky.	6			0.66														0.35			
Lincoln, Nebr.	13–14	9:09 p. m.	D. N. a. m.	1.09	9:25 p. m.	9:57 p. m.	0.01	0.20	0.27	0.33	0.37	0.45	0.51	0.57							
	31	5:25 a. m.	7:15 a. m.	0.80	5:31 a. m.	5:54 a. m.	0.01	0.25	0.43	0.58	0.68	0.73									
Little Rock, Ark.	26–27	D. N. p. m.	D. N. a. m.	0.92	12:11 a. m.	12:35 a. m.	0.02	0.17	0.30	0.43	0.48	0.55									
Los Angeles, Calif.	15			T.														T.			
Louisville, Ky.	24			0.47														0.47			
Ludington, Mich.	18	12:15 a. m.	D. N. a. m.	0.74	1:22 a. m.	1:36 a. m.	0.07	0.17	0.42	0.55											
Lynchburg, Va.	18	D. N. a. m.	D. N. a. m.	1.46	2:51 a. m.	3:39 a. m.	0.01	0.20	0.41	0.65	0.81	0.85	1.00	1.04	1.11	1.24	1.32				
	24	6:55 p. m.	7:50 p. m.	0.78	7:12 p. m.	7:37 p. m.	0.01	0.11	0.38	0.58	0.69	0.75									
Macon, Ga.	10	5:47 p. m.	8:02 p. m.	0.67	5:58 p. m.	6:15 p. m.	0.02	0.22	0.39	0.46	0.51										
Madison, Wis.	8			0.63														0.37			
Marquette, Mich.	27			1.85														0.62			
Memphis, Tenn.	6			0.82														0.53			
Meridian, Miss.	5	9:00 a. m.	10:30 a. m.	1.25	9:31 a. m.	10:24 a. m.	0.01	0.15	0.29	0.35	0.36	0.42	0.50	0.71	0.95	1.14	1.21	1.24			
		11:05 a. m.	2:00 p. m.	1.71	12:15 p. m.	12:56 p. m.	0.34	0.15	0.25	0.40	0.68	0.97	1.12	1.18	1.25	1.29					
	15	5:10 p. m.	D. N. p. m.	0.96	5:13 p. m.	5:43 p. m.	0.01	0.08	0.16	0.28	0.36	0.45	0.54								
	21	5:40 p. m.	7:15 p. m.	1.35	5:51 p. m.	6:35 p. m.	0.04	0.22	0.40	0.57	0.71	0.87	0.99	1.07	1.22	1.26					
Miami, Fla.	5	1:55 p. m.	7:15 p. m.	0.77	2:45 p. m.	3:06 p. m.	0.01	0.19	0.41	0.53	0.59	0.63									
	6	9:03 a. m.	11:47 a. m.	0.78	9:31 a. m.	9:48 a. m.	0.02	0.17	0.40	0.52	0.57										
		12:10 p. m.	2:20 p. m.	0.84	12:16 p. m.	12:38 p. m.	0.01	0.18	0.37	0.47	0.59	0.63									
	23	9:29 p. m.	9:55 p. m.	0.88	9:29 p. m.	9:49 p. m.	0.00	0.16	0.43	0.65	0.87										
	28	10:55 a. m.	12:18 p. m.	0.90	11:56 a. m.	12:11 p. m.	0.22	0.31	0.48	0.67											
Milwaukee, Wis.	8			0.19														0.15			
Minneapolis, Minn.	13			0.26														0.21			
Mobile, Ala.	10	2:09 p. m.	3:20 p. m.	0.70	2:22 p. m.	2:40 p. m.	0.04	0.13	0.41	0.53	0.64										
Modena, Utah	23			0.64														0.28			
Montgomery, Ala.	22	2:30 a. m.	6:25 a. m.	1.22	4:50 a. m.	5:16 a. m.	0.40	0.12	0.38	0.54	0.63	0.69	0.72								
	23	2:10 p. m.	3:10 p. m.	0.91	2:11 p. m.	2:44 p. m.	0.01	0.08	0.22	0.39	0.53	0.67	0.77	0.82							
Moorhead, Minn.	11	8:35 p. m.	11:10 p. m.	1.07	8:56 p. m.	9:14 p. m.	0.02	0.31	0.68	0.95	1.00										
	13	4:30 a. m.	9:00 a. m.	1.09	5:46 a. m.	6:02 a. m.	0.25	0.37	0.64	0.73	0.75										
Mount Tamalpais, Calif.	(‡)			(‡)														(‡)			
Nantucket, Mass.	15			0.57														0.48			
Nashville, Tenn.	16	1:33 p. m.	3:50 p. m.	1.33	1:39 p. m.	2:04 p. m.	0.01	0.23	0.26	0.50	0.71	0.82									
New Haven, Conn.	2–3	D. N. p. m.	1:30 p. m.	2.81	7:44 a. m.	8:09 a. m.	0.98	0.09	0.29	0.59	0.89	1.04									
New Orleans, La.	11	1:37 p. m.	3:22 p. m.	1.43	2:18 p. m.	3:02 p. m.	0.03	0.08	0.11	0.20	0.36	0.54	0.81	1.07	1.29	1.38					
	20	10:04 a. m.	10:55 a. m.	0.63	10:10 a. m.	10:28 a. m.	0.01	0.06	0,21	0.54	0.59										
	21	11:51 a. m.	1:32 p. m.	1.06	12:30 p. m.	1:03 p. m.	0.05	0.19	0.42	0.56	0.69	0.81	0.89	0.93							
	28	10:40 a. m.	11:52 a. m.	0.68	10:42 a. m.	11:15 a. m.	0.01	0.20	0.33	0.37	0.37	0.45	0.52	0.57							
New York, N. Y.	24	3:10 a. m.	6:15 a. m.	1.11	3:18 a. m.	3:43 a. m.	T.	0.05	0.27	0.62	0.70	0.75									
Norfolk, Va.	24–25	9:10 p. m.	D. N. a. m.	1.07	9:15 p. m.	9:45 p. m.	0.02	0.05	0.13	0.25	0.29	0.39	0.50								
Northfield, Vt.	14			0.65														0.54			
North Head, Wash.	12			0.68														0.18			
North Platte, Nebr.	5			0.59														0.36			
Oklahoma, Okla.	16	D. N. a. m.	10:10 a. m.	1.29	7:36 a. m.	8:10 a. m.	0.47	0.08	0.17	0.19	0.34	0.52	0.57	0.72							
Omaha, Nebr.	5			1.15														0.66			
Oswego, N. Y.	14			0.53														0.52			
Palestine, Tex.	6	3:38 a. m.	D. N. a. m.	0.64	3:41 a. m.	4:01 a. m.	0.01	0.14	0.24	0.43	0.56										
	20	10:35 a. m.	2:38 p. m.	1.63	10:48 a. m.	11:40 a. m.	0.04	0.09	0.29	0.45	0.53	0.62	0.69	0.77	0.87	1.02	1.27	1.32			
	30	3:00 p. m.	5:50 p. m.	0.77	3:02 p. m.	3:37 p. m.	0.01	0.08	0.16	0.29	0.36	0.47	0.62	0.68							
Parkersburg, W. Va.	15	9:13 a. m.	10:24 a. m.	0.80	9:23 a. m.	9:56 a. m.	0.02	0.05	0.10	0.21	0.41	0.58	0.70	0.73							
Pensacola, Fla.	11	3:20 a. m.	5:15 a. m.	0.88	3:28 a. m.	3:45 a. m.	0.03	0.14	0.32	0.46	0.61										
	19–20	10:20 p. m.	12:35 a. m.	0.90	11:59 p. m.	12:15 a. m.	0.38	0.14	0.39	0.48	0.50										
	22	3:40 a. m.	11:45 a. m.	2.08	6:54 a. m.	7:53 a. m.	0.94	0.11	0.18	0.24	0.32	0.36	0.43	0.50	0.61	0.66	0.78	0.95			
Peoria, Ill.	5–6			0.51														0.34			
Philadelphia, Pa.	7	6:15 p. m.	8:25 p. m.	0.79	6:18 p. m.	6:28 p. m.	0.01	0.35	0.56												
	23	1:55 a. m.	5:30 a. m.	0.81	3:38 a. m.	3:57 a. m.	0.03	0.09	0.23	0.49	0.63										
Phoenix, Ariz.	30			0.13														0.12			
Pierre, S. Dak.	1	8:44 a. m.	10:30 a. m.	0.64	9:44 a. m.	10:16 a. m.	0.07	0.19	0.27	0.35	0.41	0.45	0.51	0.55							
Pittsburgh, Pa.	30	5:50 p. m.	7:30 p. m.	0.68	6:08 p. m.	6:28 p. m.	0.03	0.14	0.30	0.47	0.57										
	31	3:55 p. m.	4:30 p. m.	0.62	3:59 p. m.	4:14 p. m.	0.01	0.18	0.36	0.54											
Pocatello, Idaho	30			0.09														0.09			
Point Reyes Light, Calif.	1			0.01														0.01			
Port Angeles, Wash.	12			0.52														0.27			
Port Huron, Mich.	23			0.58														0.51			
Portland, Me.	31			0.67														0.55			
Portland, Oreg.	21			0.18														0.18			
Providence, R. I.	24			1.20														0.51			
Pueblo, Colo.	18	5:27 p. m.	9:25 p. m.	1.14	5:32 p. m.	6:17 p. m.	0.01	0.15	0.32	0.53	0.68	0.72	0.75	0.79	0.86	0.91					
Raleigh, N. C.	11	3:25 p. m.	3:58 p. m.	0.62	3:32 p. m.	3:53 p. m.	0.02	0.12	0.42	0.50	0.57	0.60									
	17–18	10:50 p. m.	12:15 a. m.	1.06	11:12 p. m.	12:01 a. m.	0.01	0.24	0.43	0.57	0.64	0.67	0.72	0.77	0.88	1.00	1.05				
	25	5:00 p. m.	5:40 p. m.	0.72	5:03 p. m.	5:26 p. m.	0.01	0.09	0.23	0.44	0.65	0.71									
Rapid City, S. Dak.	12			0.53														0.53			
Reading, Pa.	22–23	11:35 p. m.	2:30 a. m.	1.20	1:09 a. m.	1:32 a. m.	0.36	0.08	0.23	0.40	0.69	0.77									
	31	7:35 p. m.	8:15 p. m.	0.90	7:43 p. m.	8:08 p. m.	0.01	0.33	0.41	0.53	0.74	0.87									
Red Bluff, Calif.	3			0.01														0.01			

* Self-register not in use. † Record partly estimated. ‡ No precipitation occurred during month.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during July, 1920, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration. From—	Total duration. To—	Total amount of precipitation.	Excessive rate. Began—	Excessive rate. Ended—	Amount before excessive rate began.	5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Reno, Nev	16			T.														T.			
Richmond, Va	2	3:16 p.m.	3:50 p.m.	0.57	3:32 p.m.	3:47 p.m.	0.02	0.15	0.29	0.55											
Richmond, Va	12	3:36 p.m.	4:30 p.m.	0.90	3:36 p.m.	3:52 p.m.	0.00	0.17	0.50	0.84	0.87										
Richmond, Va	19	4:10 p.m.	5:45 p.m.	1.10	4:40 p.m.	5:11 p.m.	0.01	0.35	0.43	0.53	0.74	0.89	1.03	1.04							
Rochester, N. Y	23			0.57														0.28			
Roseburg, Oreg	13			0.41														0.15			
Roswell, N. Mex	7			0.15														0.15			
Sacramento	(‡)			(‡)														(‡)			
Saginaw, Mich	18			0.82														0.56			
St. Joseph, Mo	4-5	9:09 p.m.	D. N. a. m.	1.82	1:37 a. m.	2:39 a. m.	0.11	0.14	0.40	0.69	1.02	1.07	1.11	1.25	1.36	1.43	1.50	1.61	1.69		
St. Louis, Mo	31			0.26														0.24			
St. Paul, Minn	13			0.41														0.40			
Salt Lake City, Utah	23			0.44														0.40			
San Antonio, Tex	30			0.11														0.11			
San Diego, Calif	1			T.														T.			
Sand Key, Fla	17			0.28														0.28			
Sandusky, Ohio	18			0.55														0.27			
Sandy Hook, N. J	3	4:15 a. m.	10:20 a. m.	1.19	5:10 a. m.	5:49 a. m.	0.13	0.05	0.15	0.33	0.53	0.63	0.82	0.98	1.03						
Sandy Hook, N. J	24	3:25 a. m.	7:20 a. m.	2.00	3:39 a. m.	5:06 a. m.	T.	0.10	0.28	0.44	0.56	0.65	0.66	0.66	0.67	0.67	0.78	0.99	1.78	1.99	
San Francisco, Calif	13-14			T.														T.			
San Jose, Calif	(‡)			(‡)														(‡)			
San Luis Obispo, Calif	1			T.														T.			
Santa Fe, N. Mex	3			0.57														0.57			
Sault Ste. Marie, Mich	23			0.70														0.34			
Savannah, Ga	10	12:50 p. m.	4:20 p. m.	1.30	1:13 p. m.	1:58 p. m.	0.06	0.26	0.40	0.50	0.66	0.77	0.87	0.94	1.02	1.07					
Savannah, Ga	16	5:21 p. m.	6:18 p. m.	0.84	5:26 p. m.	6:02 p. m.	0.01	0.12	0.20	0.45	0.51	0.54	0.62	0.74	0.77						
Savannah, Ga	22	3:38 p. m.	7:25 p. m.	1.53	3:42 p. m.	4:24 p. m.	0.01	0.10	0.22	0.52	0.71	0.95	1.07	1.11	1.22	1.26					
Scranton, Pa	7	4:11 p. m.	6:48 p. m.	1.18	4:33 p. m.	4:53 p. m.	0.01	0.26	0.40	0.59	0.73										
Seattle, Wash	12			0.87														0.22			
Sheridan, Wyo	10	7:10 p. m.	8:40 p. m.	0.81	7:42 p. m.	8:02 p. m.	0.01	0.10	0.51	0.56	0.69										
Shreveport, La	5-6	11:10 p. m.	12:15 a. m.	0.64	11:38 p. m.	12:09 a. m.	0.02	0.12	0.23	0.31	0.43	0.54	0.60	0.62							
Shreveport, La	27	5:35 p. m.	7:40 p. m.	1.18	5:45 p. m.	6:23 p. m.	0.01	0.20	0.39	0.57	0.72	0.74	0.81	0.99	1.06						
Sioux City, Iowa	4-5	8:50 p. m.	4:30 a. m.	0.69	9:05 p. m.	9:26 p. m.	0.02	0.15	0.22	0.34	0.48	0.53									
Sioux City, Iowa	13	3:25 p. m.	5:20 p. m.	1.00	4:03 p. m.	4:23 p. m.	0.01	0.35	0.67	0.79	0.87										
Spokane, Wash	13			0.43														0.31			
Springfield, Ill	1-2			0.43														0.29			
Springfield, Mo	3	6:54 p. m.	11:51 p. m.	0.98	8:03 p m.	8:22 p. m.	0.17	0.18	0.34	0.45	0.63										
Syracuse, N. Y	31			0.91														0.45			
Tacoma, Wash	12			0.74														0.15			
Tampa, Fla	10	6:52 p. m.	8:40 p. m.	2.84	6:58 p. m.	8:03 p. m.	0.01	0.17	0.40	0.73	1.14	1.36	1.74	1.99	2.19	2.34	2.45	2.60	2.78		
Tampa, Fla	17	5:30 p. m.	8:50 p. m.	1.22	6:09 p. m.	6:37 p. m.	0.06	0.16	0.37	0.64	0.86	0.93	0.97								
Tampa, Fla	19	5:35 p. m.	6:45 p. m.	1.29	5:40 p. m.	6:15 p. m.	0.02	0.07	0.13	0.38	0.68	0.90	1.08	1.15							
Tampa, Fla	21	5:30 p. m.	D.N.p.m.	1.84	5:44 p. m.	6:21 p. m.	0.03	0.27	0.80	1.05	1.12	1.17	1.21	1.26	1.30						
Tampa, Fla	27	12:45 p. m.	6:25 p. m.	1.29	1:17 p. m.	1:56 p. m.	0.20	0.09	0.12	0.18	0.23	0.38	0.59	0.67	0.75						
Tatoosh Island, Wash	30			0.26														0.08			
Taylor, Tex	4-5	8:30 p. m.	D.N.a.m.	1.95	9:31 p. m.	11:18 p. m.	0.02	0.16	0.37	0.51	0.63	0.70	0.79	0.81	0.88	0.94	0.98	1.04	1.36	1.66	1.87
Terre Haute, Ind	6	9:28 a. m.	3:15 p. m.	0.94	1:15 p. m.	1:34 p. m.	0.08	0.38	0.54	0.67	0.73										
Terre Haute, Ind	6	7:15 p. m.	11:15 p. m.	2.47	7:57 p. m.	9:09 p. m.	0.06	0.15	0.37	0.52	0.53	0.61	0.66	0.79	0.87	0.89	0.91	0.92	1.32		
Terre Haute, Ind	6				10:10 p. m.	10:24 p. m.	1.44	0.35	0.67	0.79											
Thomasville, Ga	4	9:21 a. m.	12:42 p. m.	1.34	9:23 a. m.	10:32 a. m.	0.01	0.07	0.12	0.18	0.23	0.30	0.35	0.37	0.49	0.60	0.69	0.85	1.15		
Toledo, Ohio	6	4:14 p. m.	8:05 p. m.	1.18	6:34 p. m.	7:16 p. m.	0.40	0.14	0.18	0.21	0.30	0.40	0.51	0.62	0.69	0.73					
Toledo, Ohio	14	12:50 p. m.	1:42 p. m.	1.30	1:05 p. m.	1:36 p. m.	0.01	0.27	0.62	0.85	1.06	1.16	1.24	1.28							
Tonopah, Nev	23			0.24														0.22			
Topeka, Kans	12-13	8:15 p. m.	D.N.a.m.	2.87	9:23 p. m.	10:34 p. m.	0.09	0.10	0.30	0.36	0.39	0.46	0.53	0.54	0.55	0.55	0.56	0.79	1.19		
Topeka, Kans	12-13				11:04 p. m.	11:47 p. m.	1.35	0.17	0.28	0.36	0.38	0.40	0.41	0.49	0.67	0.72					
Topeka, Kans	25-26	10:50 p. m.	10:30 a. m.	2.31	11:14 p. m.	11:50 p. m.	0.01	0.15	0.28	0.31	0.48	0.87	1.21	1.38	1.41						
Trenton, N. J	2-3			0.89														0.43			
Valentine, Nebr	5	2:53 p. m.	4:25 p. m.	0.66	3:22 p. m.	3:35 p. m.	0.01	0.38	0.53	0.58											
Vicksburg, Miss	5	D.N.a.m.	D.N.a.m.	1.08	2:13 a. m.	2:37 a. m.	0.09	0.15	0.23	0.38	0.65	0.80									
Vicksburg, Miss	6	4:13 p. m.	7:55 p. m.	0.63	6:23 p. m.	6:54 p. m.	0.01	0.07	0.22	0.32	0.35	0.39	0.48	0.53							
Vicksburg, Miss	18	5:10 p. m.	7:55 p. m.	1.10	5:23 p. m.	6:00 p. m.	0.01	0.18	0.32	0.33	0.40	0.47	0.64	0.97	1.01						
Vicksburg, Miss	19	7:42 a. m.	12:50 p. m.	2.70	7:55 a. m.	8:38 a. m.	0.03	0.12	0.27	0.36	0.51	0.76	0.98	1.31	1.59	1.80					
Walla Walla, Wash	12			0.09														0.08			
Washington, D. C.	2	6:10 p. m.	8:00 p. m.	1.42	6:40 p. m.	7:03 p. m.	0.01	0.20	0.43	0.88	1.26	1.39									
Washington, D. C.	2	9:25 p. m.	11:55 p. m.	0.88	10:51 p. m.	11:31 p. m.	0.10	0.16	0.24	0.27	0.28	0.51	0.65	0.69	0.75						
Washington, D. C.	24	3:39 p. m.	6:10 p. m.	0.89	3:42 p. m.	4:15 p. m.	0.01	0.08	0.10	0.20	0.38	0.63	0.74	0.80							
Wausau, Wis	13			0.26														0.21			
Wichita, Kans	16	D.N.a.m.	10:15 a. m.	1.48	5:07 a. m.	5:35 a. m.	0.01	0.21	0.51	0.72	0.84	0.93	0.98								
Wichita, Kans	31	5:35 p. m.	6:15 p. m.	1.50	5:41 p. m.	6:12 p. m.	0.01	0.30	0.64	0.98	1.14	1.25	1.46	1.49							
Williston, N. Dak	11			0.15														0.15			
Wilmington, N. C	8	11:47 a. m.	12:53 p. m.	0.71	11:55 a. m.	12:21 p. m.	0.03	0.20	0.23	0.23	0.29	0.50	0.51								
Winnemucca, Nev	16			T														T			
Wytheville, Va	2	5:05 p. m	5:40 p. m.	0.86	5:05 p. m.	5:25 p. m.	0.00	0.12	0.49	0.67	0.83										
Wytheville, Va	18	12:35 p. m.	2:55 p. m.	0.85	1:28 p. m.	1:48 p. m.	0.25	0.14	0.28	0.46	0.56										
Yankton, S. Dak	12			0.32														0.15			
Yellowstone Park, Wyo	19			0.15														0.14			

* Self-register not in use. † Record partly estimated. ‡ No precipitation occurred during month.

TABLE III.—*Data furnished by the Canadian Meterological Service, July, 1920.*

Stations.	Altitude above mean sea level, Jan. 1, 1919.	Pressure.			Temperature of the air.						Precipitation.		
		Station reduced to mean of 24 hours.	Sea level reduced to mean of 24 hours.	Departure from normal.	Mean maximum + mean minimum ÷ 2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	*Inches.*	*Inches.*	*Inches.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	*Inches.*	*Inches.*	*Inches.*
St. Johns, N. F	125	29.82	29.95	−.02	66.2	+6.9	74.9	57.5	90	47	3.97	+0.08	00
Sydney, C. B. I	48	29.93	29.98	+.05	65.8	+3.5	76.1	55.3	86	48	2.04	−1.61	00
Halifax, N. S	88	29.85	29.95	−.01	64.1	+0.7	74.3	54.0	90	45	4.35	+0.30	00
Yarmouth, N. S	65	29.88	29.95	.00	59.4	−0.1	66.1	52.7	74	46	5.41	+1.79	00
Charlottetown, P. E. I	38	29.86	29.90	.00	68.4	+4.3	76.4	60.3	87	52	2.89	−0.60	00
Chatham, N. B	28	29.85	29.88	.00	66.6	+1.6	77.0	56.1	90	46	4.46	+0.27	00
Father Point, Que	20	29.80	29.82	−.03	56.3	−1.3	64.0	48.6	81	43	4.48	+1.44	00
Quebec, Que	296	29.56	29.87	−.04	64.5	−1.0	73.6	55.5	85	46	5.26	+1.00	00
Montreal, Que	187	29.69	29.89	−.04	67.8	−0.7	76.2	59.5	90	49	3.04	−1.25	00
Stonecliffe, Ont	489	29.28	29.88	−.06			74.7		90		3.46	+0.34	00
Ottawa, Ont	236	29.65	29.91	−.03	65.8	−3.7	75.5	56.0	88	46	3.84	+0.37	00
Kingston, Ont	285	29.62	29.92	−.05	64.2	−4.0	71.5	56.9	79	47	3.18	+0.29	00
Toronto, Ont	379	29.55	29.94	−.03	66.4	−1.6	76.7	56.1	87	44	3.63	+0.71	00
Cochrane, Ont	930												
White River, Ont	1,244	28.60	29.90	−.04	56.4	−3.1	70.6	42.2	82	29	3.11	+0.31	00
Port Stanley, Ont	592	29.34	29.98	.00	64.1	−3.7	74.6	54.7	83	39	3.79	+0.75	00
Southampton, Ont	656	29.25			61.2	−3.5	69.8	52.6	81	42	3.18	+1.20	00
Parry Sound, Ont	688	29.28	29.96	.00	63.7	−2.3	74.0	53.4	86	45	4.23	+1.61	00
Port Arthur, Ont	644	29.25	29.96	+.02	61.7	−0.3	73.1	50.3	84	39	3.54	+0.06	00
Winnipeg, Man	760	29.15	29.96	+.03	66.4	+0.4	79.6	53.3	90	39	0.76	−2.32	00
Minnedosa, Man	1,690	28.19	29.97	+.04	65.3	+3.1	79.2	51.4	93	36	2.55	−0.05	00
Le Pas, Man	860												
Qu'Appelle, Sask	2,115	27.76	29.96	+.04	66.2	+2.7	80.7	51.7	98	37	3.94	+1.46	00
Medicine Hat, Alb	2,144	27.68	29.88	−.02	73.0	+5.2	87.9	58.2	98	46	2.03	−0.06	00
Moose Jaw, Sask	1,759												
Swift Current, Sask	2,392	27.43	29.99	+.08	68.0	+1.5	82.7	53.3	97	40	2.16	−0.28	00
Calgary, Alb	3,428	26.52	30.01	+.11	65.8	+5.2	81.4	50.2	92	43	4.94	+2.26	00
Banff, Alb	4,521	25.50	29.98	+.08	61.7	+5.1	78.6	44.8	88	38	1.86	−1.38	00
Edmonton, Alb	2,150	27.73	29.97	+.07	65.1	+4.5	78.7	51.5	92	44	2.33	−0.70	00
Prince Albert, Sask	1,450	28.43	29.98	+.07	66.3	+4.4	80.7	51.9	95	41	0.85	−1.20	00
Battleford, Sask	1,592	28.26	29.97	+.07	66.3	+1.6	79.2	53.5	94	45	3.98	+1.64	00
Kamloops, B. C	1,262	28.76	30.02	+.08	73.4	+4.9	88.4	58.5	97	48	0.35	−1.26	00
Victoria, B. C	230	29.80	30.05	.00	59.8	−0.2	68.0	51.5	91	49	1.00	+0.60	00
Barkerville, B. C	4,180	25.77	30.03	+.12	56.2	+1.1	69.5	42.9	82	31	3.56	+0.54	00
Triangle Island, B. C	680												
Prince Rupert, B. C	170												
Hamilton, Ber	151	30.11	30.27	+.13	77.0	−1.7	82.8	72.1	85	65	3.53	−0.91	00

SEISMOLOGICAL REPORTS.

W. J. HUMPHREYS, Professor in Charge.

[Weather Bureau, Washington, D. C., Sept. 3, 1920.]

TABLE 1.—*Noninstrumental earthquake reports, July, 1920.*

Day.	Approximate time, Greenwich civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		CALIFORNIA.								
1920.	*H. m.*		° ′	° ′			*Sec.*			
5	15 55	Whittier	34 00	118 04	3	1		None	Felt by several	Associated Press.
10	5 25	Los Angeles	34 03	118 15	3–4	3?	1–2	do	do	P. Hansen.
16	18 08	Los Angeles	34 03	118 15	6	1	4 *ca.*	do	Felt by everyone	H. B. Hersey.
	21 26	Pasadena	34 65	118 10	3	1	5	do	Felt by many	M. S. Jones.
	21 27	Los Angeles	34 03	118 15	6	1	3	do	Felt by everyone	H. B. Hersey.
	21 27	Mt. Wilson	34 13	118 16	2	1	1–2	do	Felt by several	W. P. Hoge.
	21 30	Los Angeles	34 03	118 15	6	1	3	do	Felt by everyone	H. B. Hersey.
		Mt. Wilson	34 13	118 16	3	1	1–2	do	Felt by several	W. P. Hoge.
		Pasadena	34 65	118 10	6	1	10	do	General alarm	M. S. Jones.
17	2 14	Los Angeles	34 03	118 15	3	1	1	do	Felt by several	R. F. Young.
23	3 55	McCloud	41 15	122 10	3	1		do	do	George Buxton.
	4 00	Redding	40 35	122 25	8	1		do	Windows broken, chimneys demolished.	Associated Press.
	14 00	Redding	40 35	122 25	6	1		do	Felt by many	Do.
	16 00	Redding	40 35	122 25	6	1		do	do	Do.
	20 00	Redding	40 35	122 25	6	1		do	do	Do.
26	12 12	Los Angeles	34 03	118 15	3	2	1–2	Faint	Felt by several	R. F. Young.
	12 15	Los Angeles	34 03	118 15	4	1	2	Rattling	Awoke light sleepers	J. M. Bartley.
27	8 02	Los Angeles	34 03	118 15	3	1	1–2	Faint	Felt by several	R. F. Young.
28	19 28	Los Angeles	34 03	118 15	4	1	2	None	do	H. B. Hersey.
		SOUTH DAKOTA.								
14	23 00	Oelrichs	43 15	103 15	?	1	Few.	do		J. E. Strouse.
		Hot Springs	43 30	103 25	?	1	2	Rumbling	No damage	Allen Baker.
		LATE REPORTS.								
Apr. 14	11 45	Crater Lake, *Oreg.*	42 50	122 00	5	3	Short.	do	Also felt at Fort Klamath	H. F. Brown.
May 18	18 00	Santa Monica, *Calif.*	34 02	118 30	3	1	1	None	Felt by several	N. Barker-Bates.
June 5	14 01	Summerville, *S. C.*	33 05	80 15	1	1		Faint	do	Mrs. E. G. Robertson.

TABLE 2.—*Instrumental Reports, July, 1920.*

[For significance of symbols and abbreviations, and for a description of stations and instruments, see the REVIEW for January, 1920, pp. 62-63.]

ALASKA. *U. S. C. & G. S. Magnetic Observatory, Sitka.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
July 7		P_N	18 42 49					Instrument in poor adjustment; E not in operation.
		L_N	18 44 17					
		M_N	18 44 26	10		460		
		C_N	18 45 20					
		F_N	18 48 25					

ARIZONA. *U. S. C. & G. S. Magnetic Observatory, Tucson.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
July 7		L_E	18 59 10					
		e_N	19 00 26					
		M_E	19 01 10	13	10	10		
		C_E	19 04 ..					
		F	19 12 ..					

CALIFORNIA. *Theosophical University, Point Loma.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
July 1					150	250		Tremors during 24 h. preceding 15 h. that date.
2					200	250		
3					200	300		
4					100	100		Do.
5					50	50		Do.
6					150	150		Do.
8					200	200		Do.
10					200	400		Do.
11					100	100		Do.
13					100	200		Do.
14					200	200		Do.
15					100	150		Do.
16					100	250		Do.
			18 00 *ca*		200	200		
17					150	150		Tremors as above.
18					200	200		Do.
19					200	200		Do.
20					150	300		Do.
21					100	100		Do.
25					100	100		Do.
27					250	400		Do.
28					300	300		Do.
29					200	250		Do.

DISTRICT OF COLUMBIA. *U. S. Weather Bureau, Washington.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
July 2		P?	3 21 08					Amplitudes small.
		S	3 24 15					
		F	3 35 *ca*					
5								Feeble quake about 10:12; record uncertain.
7		P	18 49 40					L not found.
		S	18 56 20					
		M	19 05 25		*16,500	*16,500		
		F	19 50 *ca*					
7		e	23 33 30					
		F	23 45 *ca*					
8		e	0 59 30					
		F	1 20 *ca*					
16		P	17 20 36					
		S?	17 26 30					
		L	17 32 20	20				
		F	20 45 *ca*					
26		P	5 23 57				7,000	
		S	5 33 15					
		F	5 50 *ca*					

* Trace amplitude.

HAWAII. *U. S. C. & G. S. Magnetic Observatory, Honolulu.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1920			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
July 2		P	18 50 30	18				
		S	18 58 18	17				
		SR_2	19 03 54	15				Very considerable increase in amplitude.
		eL	19 07 00	17				
		M	19 15 36	16	*1,300			
		C	19 30 ..	17				
		F	20 26 ..	17				

HAWAII. *U. S. C. & G. S. Magnetic Observatory, Honolulu*—Continued.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
July 2		P	21 49 12	17				
		S	21 59 36	17				
		eL	22 16 00	17				
		M	22 25 24	17	*800			
		C	22 30 ..	17				
		F	23 19 ..	17				
6		eP	3 09 12					
		S	3 17 00	18				
		iSR_1	3 21 54					Most marked phase.
		eL	3 28 00	17				
		M	3 34 00	17	*500			Actual maximum 3:23:2.
		C	3 37 ..	16				
		F	4 10 ..	16				
7		L	18 59 12					
		M	19 01 00	18	*300			
		C	19 03 00					
		F	19 17 ..					
7		L	20 28 30	18				
		M	20 33 30	18	*200			
		C	20 41 ..	15				
		F	20 44 ..					
20		eP	0 56 00					Tremors also at 5:35:36 and 12:51:30.
		L	1 00 00					
		M	1 05 00	18	*200			
		C	1 13 ..	18				
		F	1 49 ..					

* Trace amplitude.

ILLINOIS. *U. S. Weather Bureau, Chicago.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1920			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
July 2		P	18 59 42					
		S?	19 09 18					
		eL	19 30 40					
		L	19 36 30	23				
		L	19 42 ..	18				
		L	19 50 ..	15				
		F	21 30 *ca*					
2		P	21 58 20				9,000	
		S	22 08 30					
		eL	22 31 30					
		L	22 44 30	20				
		L	22 55 ..	16				
3		F	0 20 ..					
3		P	16 40 38				2,900	
		S	16 45 13					
		eL	16 49 ..					
		F	17 30 *ca*					
4		P	0 33 33					
		S?	0 38 ..					
		eL	0 48 ..					
		L	0 50 ..	24				
		L	0 55 ..	16				
		F	1 20 *ca*					
5		P	10 10 23					
		S?	10 11 ..					
		L?	10 11 06	11				
		F	10 25 *ca*					
6		P	3 25 57					
		S	3 36 04					
		eL	3 50 ..					
		L	4 00 00	18				
		L	4 10 ..	16				
		F	4 50 *ca*					
7		P	18 48 40				3,800	
		S	18 54 28					
		L	18 56 50	15				
		M	19 01 15		*12,000	*12,000		
		F	20 15 *ca*					
7		P	23 18 00					
		S	23 23 58					
		F	23 55 *ca*					
8		P?	0 46 15					L not discernible.
		S	0 52 05					
		F	1 40 *ca*					
11		P	1 47 12					L not found.
		S	1 55 30				6,800	
		F	3 *ca* —					

* Trace amplitude.

TABLE 2.—*Instrumental Reports, July, 1920*—Continued.

ILLINOIS. *U. S. Weather Bureau, Chicago*—Continued.

1920.			H. m. s.	Sec.	μ	μ	Km.	
July 16		P	17 21 57				3,400	
		S	17 27 05					
		L	17 35 —	16				
		F	18 30 *ca*					
20		e	1 08 30					May not be seismic.
		F	1 40 *ca*					
20		P?	5 31 54					
		S?	5 40 15					
		L	5 48 —	18				
		F	6 40 *ca*					
25		P?	13 28 20					Very feeble.
		F	14 *ca* —					
26		P	5 24 20				8,300	
		S	5 33 55					
		L	5 50 20					
		F	6 40 *ca*					
28		e	0 55 —					
		F	1 30 *ca*					

MARYLAND. U. S. C. & G. S. *Magnetic Observatory, Cheltenham.*

1920			H. m. s.	Sec.	μ	μ	Km.	
July 7		e_E	18 56 24					
		e_N	19 00 00					
		eS_E	19 01 17	3				
		L_E	19 04 05					
		eL_N	19 04 35	13				
		M_E	19 05 35	13	220			
		M_N	19 05 40	13		200		
		C_E	19 10 —					
		C_N	19 09 —					
		F_E	19 30 —					
		F_N	19 27 —					
8		e_E	1 02 12		10			No distinct phases.
		e_N	1 02 07			20		
		F_E	1 09 —					
		F_N	1 11 —					

CANAL ZONE. *Panama Canal, Balboa Heights.*

1920.			H. m. s.	Sec.	μ	μ	Km.	
July 1		P_E	15 18 28				249	Direction probably SW.
		P_N	15 18 30					
		S_E	15 18 55					
		S_N	15 18 57					
		M_E	15 18 59		*300			
		M_N	15 19 01			*100		
		F_E	15 21 00					
		F_N	15 20 45					
16		P_E	17 15 42				483	Direction probably NW.
		P_N	17 15 44					
		S_E	17 16 34					
		S_N	17 16 36					
		L_E	17 16 50					
		L_N	17 16 51					
		M_E	17 17 11		*6,000			
		M_N	17 17 23			*8,000		
		F_E	17 27 10					
		F_N	17 32 30					
19		P_E	15 04 16				407	Do.
		P_N	15 04 10					
		L_E	15 05 12					
		L_N	15 05 06					
		M_E	15 05 14		*800			
		M_N	15 05 12			*800		
		F_E	15 08 00					
		F_N	15 10 00					

*Trace amplitude.

VERMONT. *U. S. Weather Bureau, Northfield.*

1920.			H. m. s.	Sec.	μ	μ	Km.	
July 2		eL	19 43 ..					
		L	19 47 ..	20				
		F	20 00 *ca*					
7		P	18 47 55					
		M	19 03 36					Trace amplitude 4 mm.
		F	19 30 *ca*					

CANADA. *Dominion Observatory, Ottawa.*

1920.			H. m. s.	Sec.	μ	μ	Km.	
May 30		e_N						Lost in micros. Quake omitted from May report as it appeared to to be local.
		e_E	21 05 ..					
		eL?	21 06 20					
		M_N	21 07 50					
		F	21 35 00					
July 2		e						Lost in small micros at about 19h. From deformation instrument only; 18 mm.=1 h.
		PR_1?	19 11 *ca.*					
		eS?	19 16 *ca.*					
		eL	19 38 ..	50				
		L	19 47 ..	20				
		L_E	19 56 ..	18				
		L_E	20 10 ..	15				
		F	20 30 ..					
2		e	21 55 54					May not be seismic.
		eL	21 59 48					
		F	22 40 ..					
7		O?	18 41 34				4,160	
		P?	18 49 04					
		$S?_N$	18 55 00					
		eL	19 00 *ca.*					
		L	19 10 ..					Irregular.
		F	19 45 ..					
7		e_N	23 22 48					Small irregular record.
		eL	23 32 00					
		M_N	23 35 ..					
		F	23 55 ..					
8		e_N	0 54 00					Small irregular record.
		e	0 58 20					
		M_N	1 03 ..					
		F	1 35 00					
11		e_N	1 40 40					Small irregular waves resembling micros.
		i	1 48 12	4				
		i	1 50 08	6				
		e	1 55 30					
		F	2 02 20					
16		O	17 15 54					NS lost in generator disturbance.
		P_E	17 22 54					
		S_E	17 28 30					
		L_E	17 32 54	26				
		L_E	17 40 ..	12				
		F	18 00 ..					
26		e	5 34 40					Faint trace only.
		F	6 00 00					

CANADA. *Dominion Meteorological Service, Toronto.*

1920.			H. m. s.	Sec.	μ	μ	Km.	
July 2		L?	19 38 42					P, S, and F masked by micros.
		eL	19 43 36					
		M	19 51 54		*1,300			Thickening.
		iL	20 04 12					
2		L	21 42 12					
		M	21 52 06		*200			
		F	22?07 48					
3		L	16 52 30					
			to 58 42		*200			
4		L?	0? 52 36					
		L	to 57 36		*200			
4								Marked oscillation of *400 between 15h. 26m. 42s. and 15h. 30m.; may be local.
6		eL	3 37 36					
		F	3 40 24		*200			
6		eL	4 08 06					
		M	4 11 06		*400			Gradual thickening.
		F	4 18 54					
7		iL	19 02 36					
		M	19 02 54		*900			
		F	19 36 06					
16		L	17 32 42					
		M	17 33 54		*300			Marked micros going on.
		L?	18?03 30					
		F						Micros.
26		L?	5 17 30					
		iL	5 29 12					
		M	5 30 30		*300			Micros at intervals.
		F	5 36 00					

* Trace amplitude.

TABLE 2.—*Instrumental Reports, July, 1920*—Continued.

CANADA. *Dominion Meteorological Service, Victoria.*

1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
July 2		P	19 04 04				4,120	
		S	19 09 58					
		L	19 21 46					
		M	19 27 40		*4,000			
				VERTICAL.				
		M	*19?27 00*	*25*	*3*			
2		P	21 58 37					
		M	22 35 03		*400			
		F	22 51 46					
3		P	16 51 47					
		L	16 55 43					
		M	16 58 40		*200			
		F	17 10 29					
4		P	1?02 38					
		M	1 07 33		*200			
		F	1 15 25					
6		P	3?24 21					
		M	3 26 19		*100			
6		M	3 44 00		*100			
		F	3 57 30					
7		P	18 48 02				820	
		L	18 49 31					
		M	18 50 29		*1,750			
		F	19 13 08					
				VERTICAL.				
		P	*18 46 30*	*3*			1,320	Probably off north coast of California.
		S	*18 48 50*	*6*				
		L	*18 52 00*	*8*				
		M	*18 55 15*	*8*	*14*			
7		M	20?46 34		*100			
8		P	2 54 26					
		M	3 00 50		*200			
		F	3 05 45					
16		P	17 37 33					
		M	17 50 01		*200			
		F	18 06 05					
20		P	1 09 36					
		L	1 12 13					
		M	1 13 12		*200			
		F	1 20 04					
26		P?	5 36 04					
		L?	5 56 43					
		M	6 02 38		*200			
		F	6 12 58					

* Trace amplitude.

No earthquakes were recorded at the following stations during July, 1920:

COLORADO. *Sacred Heart College*, Denver.

Reports for July, 1920, have not been received from the following stations:

ALABAMA. *Spring Hill College*, Mobile.
DISTRICT OF COLUMBIA. *Georgetown University, Washington.*
KANSAS. *University of Kansas*, Lawrence.
MASSACHUSETTS. *Harvard College*, Cambridge.
MISSOURI. *St. Louis University*, St. Louis.
NEW YORK. *Canisius College*, Buffalo; *Cornell University*, Ithaca; *Fordham University*, New York.
PORTO RICO. *U. S. C. & G. S. Magnetic Observatory*, Vieques.

TABLE 3.—*Late Reports (Instrumental).*

CALIFORNIA. *Theosophical University*, Point Loma.

1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
April 3					400	400		Tremors during 24 hrs. preceding 15h. this date.
4					250	250		Do.
5					250	250		Do.
6					200	200		Do.
7					200	250		Do.
8					100	100		Do.
13			4 43 *ca*		400	500		Light shock; int. II, R-F.
19					200	200		Tremors as above.
21					300	400		Do.

TABLE 3.—*Late Reports (Instrumental)*—Continued.

CALIFORNIA. *Theosophical University*, Point Loma—Continued.

1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
May 7					100	100		Tremors as above.
12					100	100		Do.
13					100	100		Do.
14					50	50		Do.
15					100	150		Do.
17					200	200		Do.
19					100	100		Do.
20					100	100		Do.
21			13 50 ..		250	250		Light shock.
			14 20 ..					Do.
25					50	50		Tremors as above.
26					100	150		Do.
28					100	100		Do.
29					50	50		Do.
30					150	150		Do.
31					100	100		Do.
June 6					50	50		Do.
7					50	50		Do.
8					100	100		Do.
9					100	100		Do.
10					200	300		Do.
13					50	100		Do.
16					100	50		Do.
17					100	100		Do.
18					100	150		Do.
19					100	150		Do.
20					50	50		Do.
21					100	100		Do.
22			2 67 ..		150	350		Light shock.
			15 00 ..		150	150		Tremors.
23					200	300		Tremors as above.
26					200	450		Do.
26					50	100		Do.
27					100	100		Do.
28					100	100		Do.
29					250	350		Do.
30					100	200		Do.

DISTRICT OF COLUMBIA. *Georgetown University, Washington.*

1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
June 2		eP_E	22 18 46					
		eP_N	22 18 46					
		S_E?	22 22 36					
		S_N?	22 22 36					
		eL_E	22 23 30					
		eL_N	22 23 36					
		L_E	22 24 42	8				
		L_N	22 24 24	8				
		F	22 51 ..					
5		eP_E	4 40 48					
		eP_N	4 40 48					
		S_E	4 48 10					
		S_N	4 48 13					
		eL_E	4 57 18					
		L_E	5 18 21					
		L_N	5 28 27					
		M_E	5 38 16	16	*600			
		M_N	5 37 16	16		*1,200		
		F	6 30 ..					
9		e_E	11 53 ..					Heavy micros. Difficult.
		e_N	11 53 ..					
		F	12 20 ..					
18		eP_E	10 25 43					
		eP_N	10 25 49					
		S_E?	10 28 49					
		eL_E	10 29 42	9				
		F	10 45 ..					
22		e_E	3 05 ..					
		e_N	3 05 ..					
		S_E?	3 10 44					
		F	3 18 ..					

* Trace amplitude.

MASSACHUSETTS. *Harvard University, Cambridge.*

1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
June 2		O?	22 12 35				2733?	Distance may be greater and 0 earlier by one or more minutes. Phases on both components indistinct before 22h 24m *ca.* N record distorted by local disturbances and micros. F uncertain, in micros.
		e_E	22 21 38	4				
		S_E?	22 22 29	6				
		L_E	22 23 51	12				
		eL_E	22 24 34	10				
		M_E	22 25 23	11				
		M_E	22 26 42	8				
		C_E?	22 28 43	7 & 10				
		F_E?	23 12 *ca*					

TABLE 3.—*Late Reports (Instrumental)*—Continued.

MASSACHUSETTS. *Harvard University, Cambridge*—Continued.

1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
June 4		O	15 *postea*					Earlier phases not distinguishable from micros before and after this record. Press dispatches mention two quakes felt at Ferrara, Italy, on June 5.
		eL_E?	15 45 51	12				
		M_E	15 48 52	10				
		M_N?	15 55 06	10				
		F?	16 15 *ca*					
5		O	4 21 26				11,500	104.04° of arc: eL–0 gives V_1 228 kms. sec.
		eP_E?	4 39 08					
		iP_E	4 40 45					
		iP_N	4 40 51	6				
		S_E	4 50 36	10				
		S_N	4 51 45	13				
		SR_N?	4 56 32					
		eL_E	4 12 08	54				
		eL_N	4 12 42	54				
		L_N	4 13 32	50				
		L_E	4 15 00	40				
		L_E	4 19 00	30				
		L_E	4 20 00	20				
		M_E	4 27 08	18	107?			E damped 1.5/1 only. Chief maximum.
		M_E	5 31 00	18	170?			
		C_E	5 34 00					
		F	6 50 *ca*					
9		O	11 *postea*				13,000+	
		e_E	11 50 15	6				
		e_N	11 50 27	6				E record changed from 12h 14m to 12h 30m; N record has hiatus between 12h 4m and 12h 16m.
		e_N	11 53 21	10				
		e_E	11 53 24	12				
		e_N	11 54 29	12				
		eL_N	12 34 40	60				
		eL_E	12 34 43	40				
		L_E	12 35 24	60				eL–e, 44m 25s: i_E 12:11:21 8 secs. L waves very flat. S well marked for flat L.
		L_E	12 36 08	60				
		L_E	12 39 48	30				
		L_E	12 55 34	20				
		L_N	13 08 00	20				
		C_{EN}	13 11 00	15				
		F_E						After 13h 35m; Lost in micros and artificial motion.
12		O	20 *postea*					Not recognizable on E.
		eL_N?	20 56 26	28				
		L	21 01 21	14				
		L	21 03 17	12				
		F?	21 46 *ca*					
16		e_E?	20 12 56					Record of doubtful origin; micros only on N.
		i?	20 14 54	8				
		e_E	20 17 53	8				
		L_E	20 26 04	15				
			20 28 *ca*	8				
		F?	20 30 *ca*					Lost in winding drums.
18		O	9 *postea*					Apparently seismic; masked by micros; and not clear.
		$P?_N$	9 03 54					
		$S?_N$	9 05 30	6				
		$L?_N$	9 05 42	10				
		L?	9 08 47	10				
		$L?_N$	9 11 13	15				
		L?	9 13 12	10				
		F?	9 15 ..					
18		O	9 *postea*					Apparently seismic and not distant.
		$S?_N$	9 45 36	6				
		L?	9 47 29	8				
18		O	10 22 27				1,450	E masked by micros; distance from epicenter and O from eLn and Sn–Pn.
		eP_E?	10 25 42	3				
		eP_N	19 25 49	3				
		S_N	10 28 25	6				
		eL_N	10 29 00	13				
		eL_E?	10 29 01					

MASSACHUSETTS. *Harvard University, Cambridge*—Continued.

1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
June 18		M_N	10 29 20	11				A 625μ trace.
		M_E	10 31 30					Perceptible.
		F						In next quake.
18		O?	10 36 31				675?	Confused with last record on E, and somewhat masked by micros. No reports; may be part of last record.
		P_N	10 38 02	3				
		S_N	10 39 16					
		eL_N?	10 39 56	12				
		F?	10 48 *ca*					
21		O?	14 06 23				3,080?	Fore phases masked by micros. No M.
		S_N	14 17 20	6				
		eL_N?	14 19 57	28				
		L_E	14 20 01	20				
		C_N	14 22 40	6				
		F	14 26 18					
22		O?	1 45 *ca*				3,866?	O from press dispatches, giving time of a destructive shock at Inglewood, about 10 miles SW. from Los Angeles, at 6^h 45^m, 6^h 46^m, 6^h 47^m, June 21, 120th mer. time W. Distance from station to courthouse in Los Angeles is 3,850 kms. Press reports 21 buildings destroyed, several persons slightly injured. In Los Angeles plate glass windows shattered. Shock causing damage followed by two tremors few minutes later. At 10^h 40^m p. m. a fourth tremor felt at Inglewood and SW part of Los Angeles; slight shock 4 a. m. June 22. Other press notices give time 5^h a. m. 120 mer. W. Harvard record after 2:07:58, from time given for O, would appear to be C vibrations.
		*eL_E?	2 01 19	24	Faint			
		i_E	2 07 58	3				
		i_N	2 08 15	10				
		i_N	2 08 26		M			
		i_N	2 08 29	14				
		e_E	2 08 31	12				
		e_E	2 08 43	6				
		e_E	2 08 51	6 & 8				
		F_N	2 22 *ca*					
		F_E	2 35 *ca*					

* Possibly of different origin.

PORTO RICO. U. S. C. & G. S. *Magnetic Observatory, Vieques.*

1920.			*H. m. s.*	*Sec.*	μ	μ	*Km*	
June 5		e_N	4 42 57					Probably PR_1; reported from Formosa.
		eL_E	5 26 10	20				
		eL_N	5 39 07	22				
		M_E	5 40 25	20				
		M_N	5 44 20	22				
		C_E	5 54 ..	19				
		C_N	5 47 ..	22				
		F_E	6 24 ..	18				
		F_N	5 52 ..					

Chart I. Hydrographs of Several Principal Rivers, July, 1920.

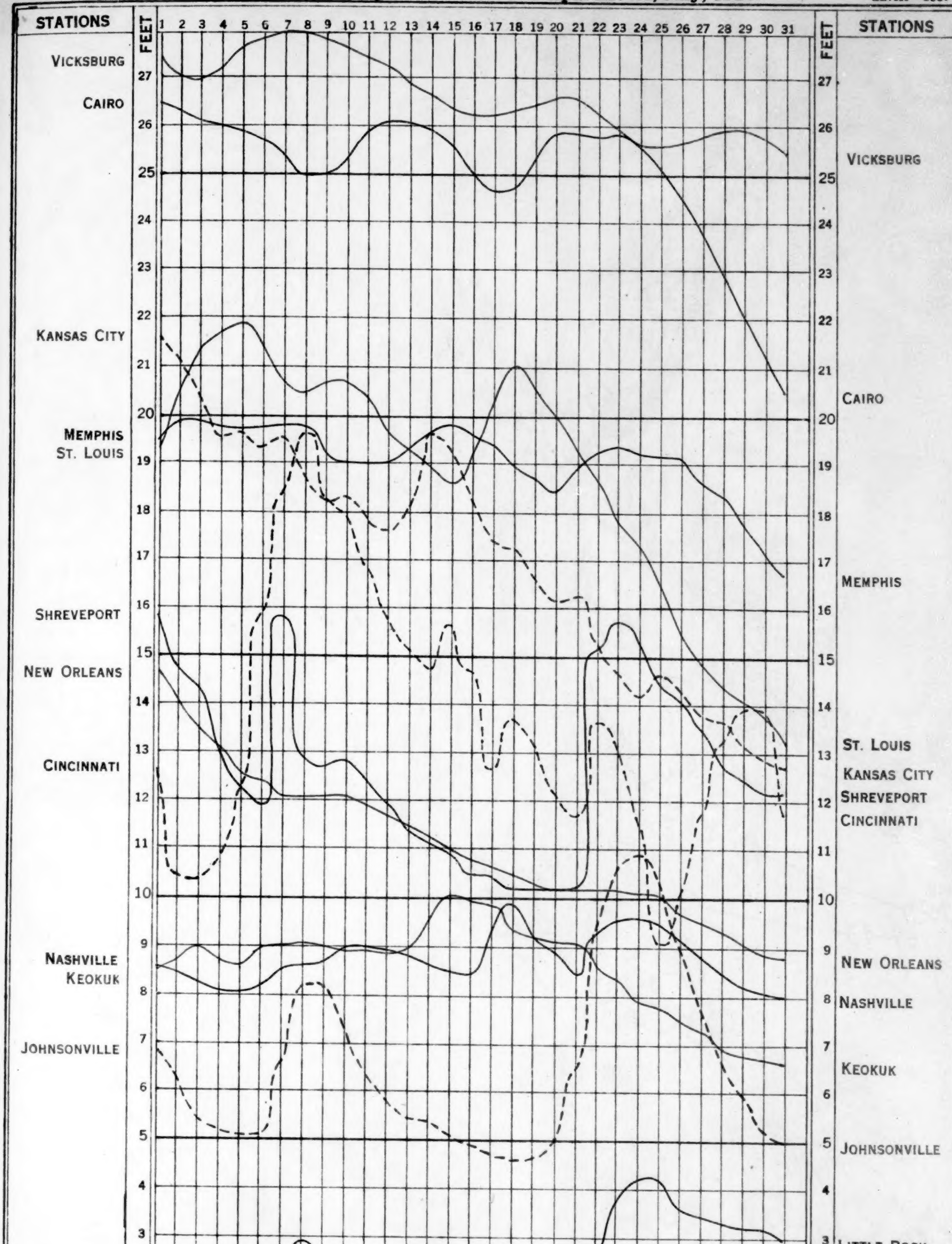

Chart II. Tracks of Centers of High Areas, July, 1920.
(Plotted by R. H. Weightman, Meteorologist.)

Chart III. Tracks of Centers of Low Areas, July, 1920.

(Plotted by R. H. Weightman, Meteorologist.)

Chart IV. Departure (°F.) of the Mean Temperature from the Normal, July, 1920.

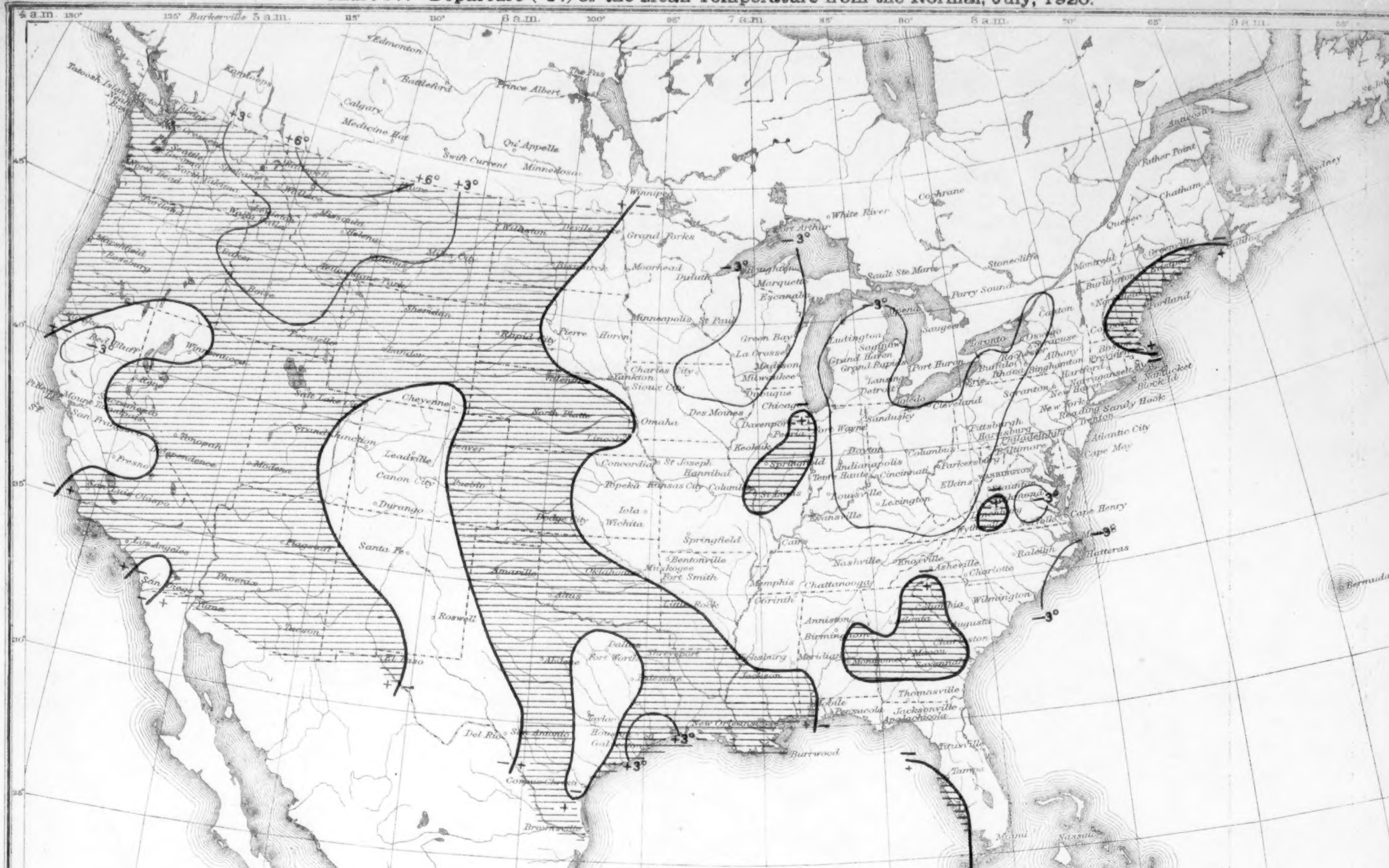

Chart V. Total Precipitation, Inches, July, 1920.

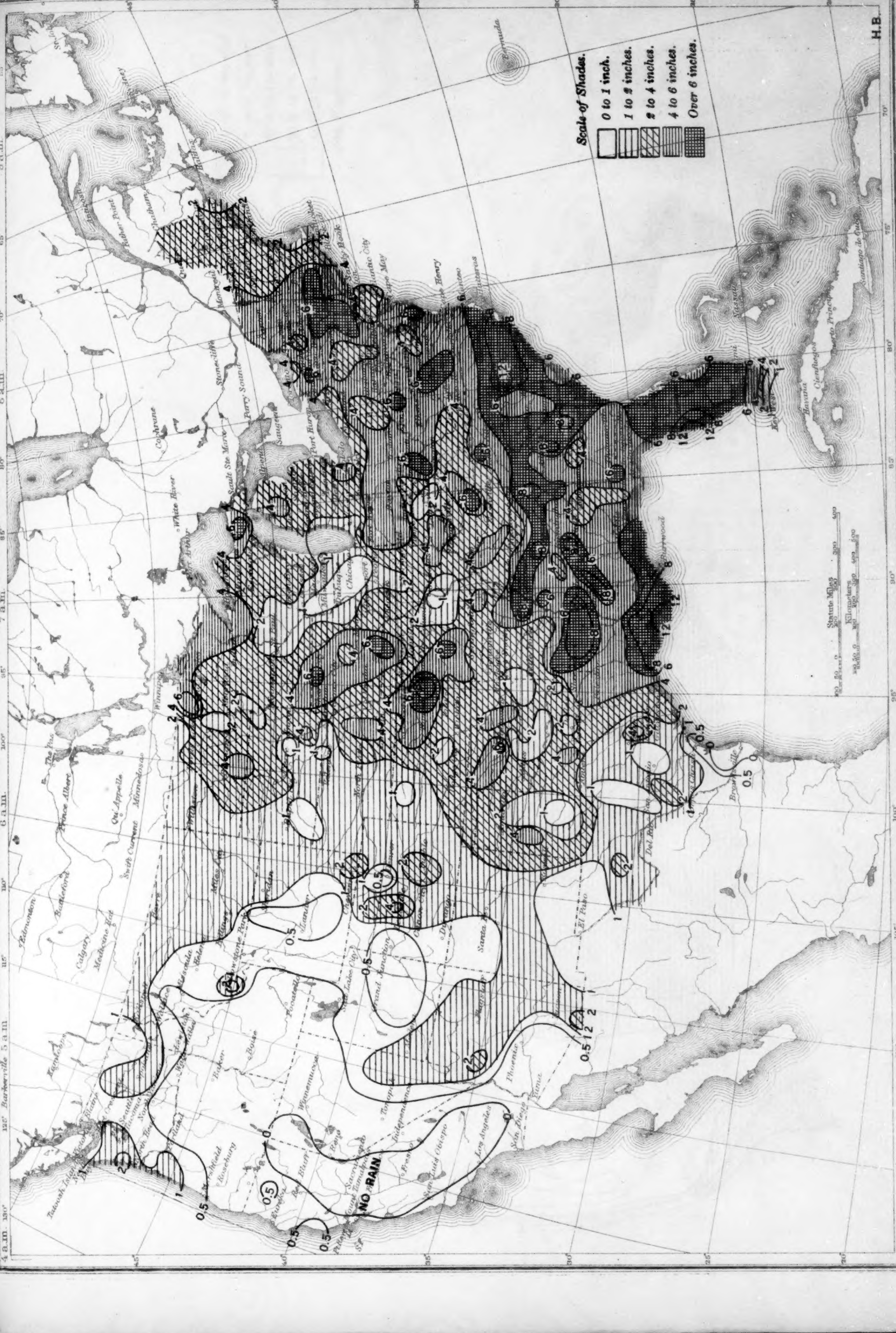

Chart VI. Percentage of Clear Sky between Sunrise and Sunset, July, 1920.

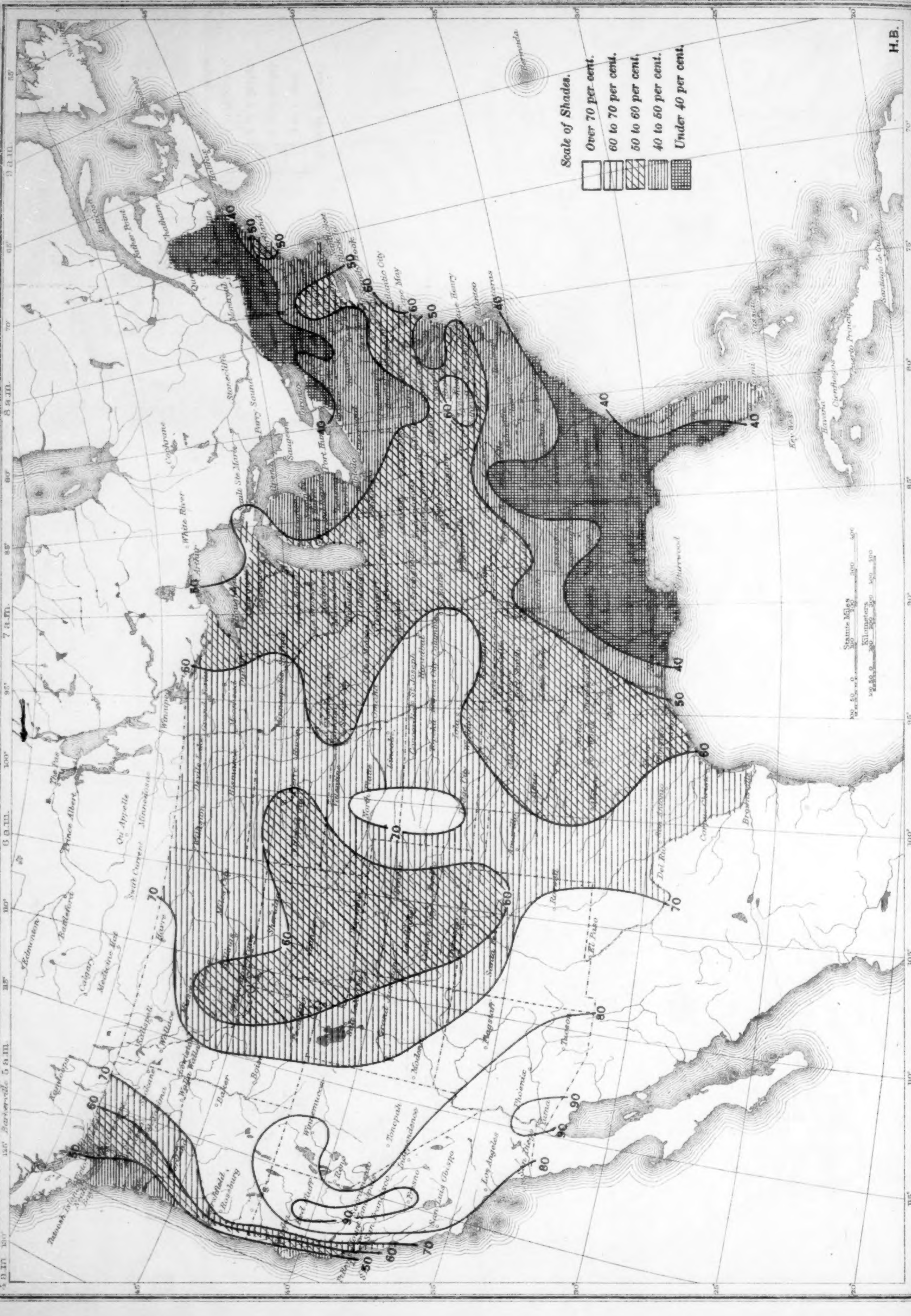

Chart IX. Weather Map of North Atlantic Ocean, July 29, 1920.

(Plotted by F. A. Young.)

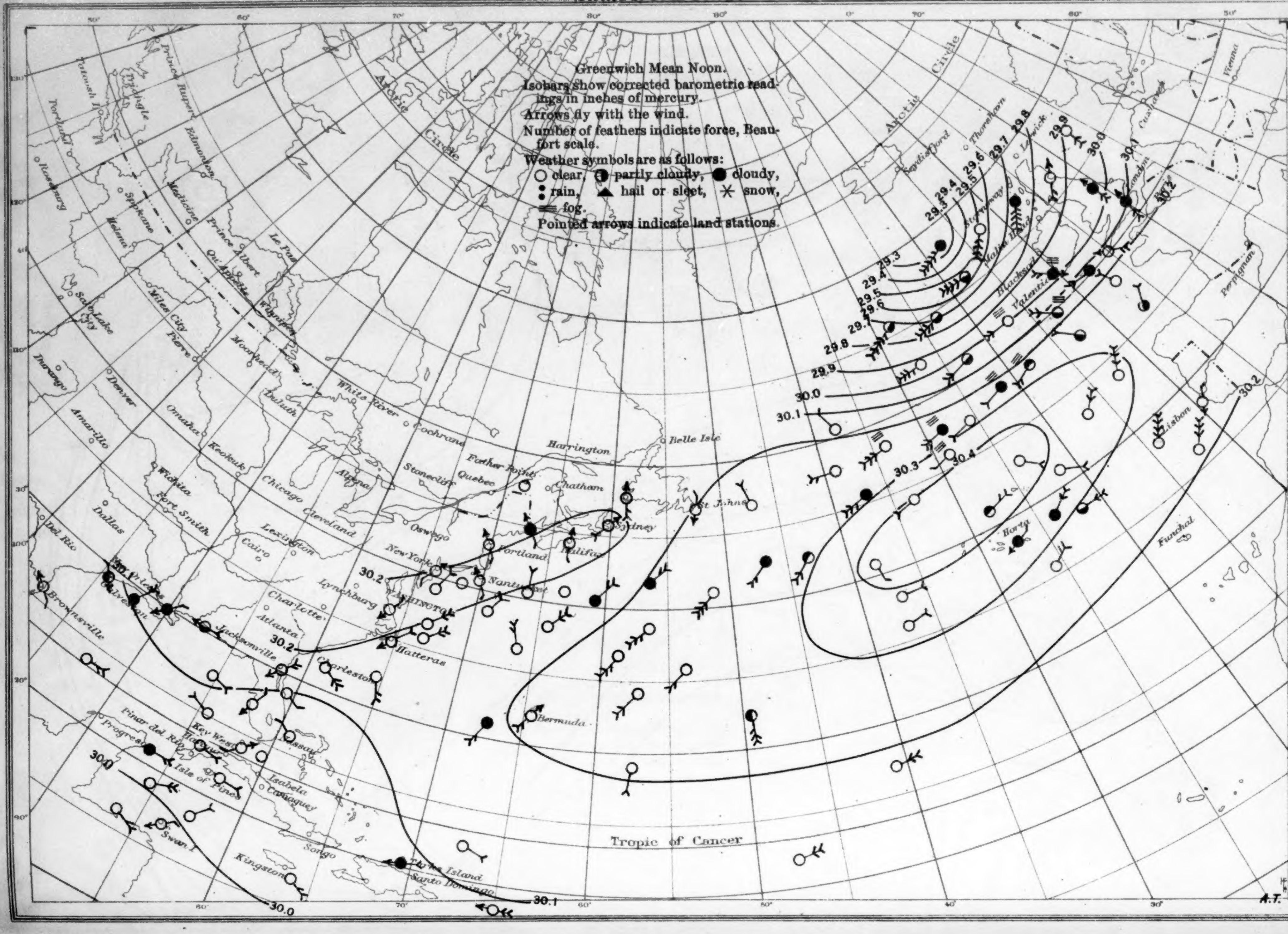

Chart VII. Isobars and Isotherms at Sealevel; Prevailing Winds, July, 1920.

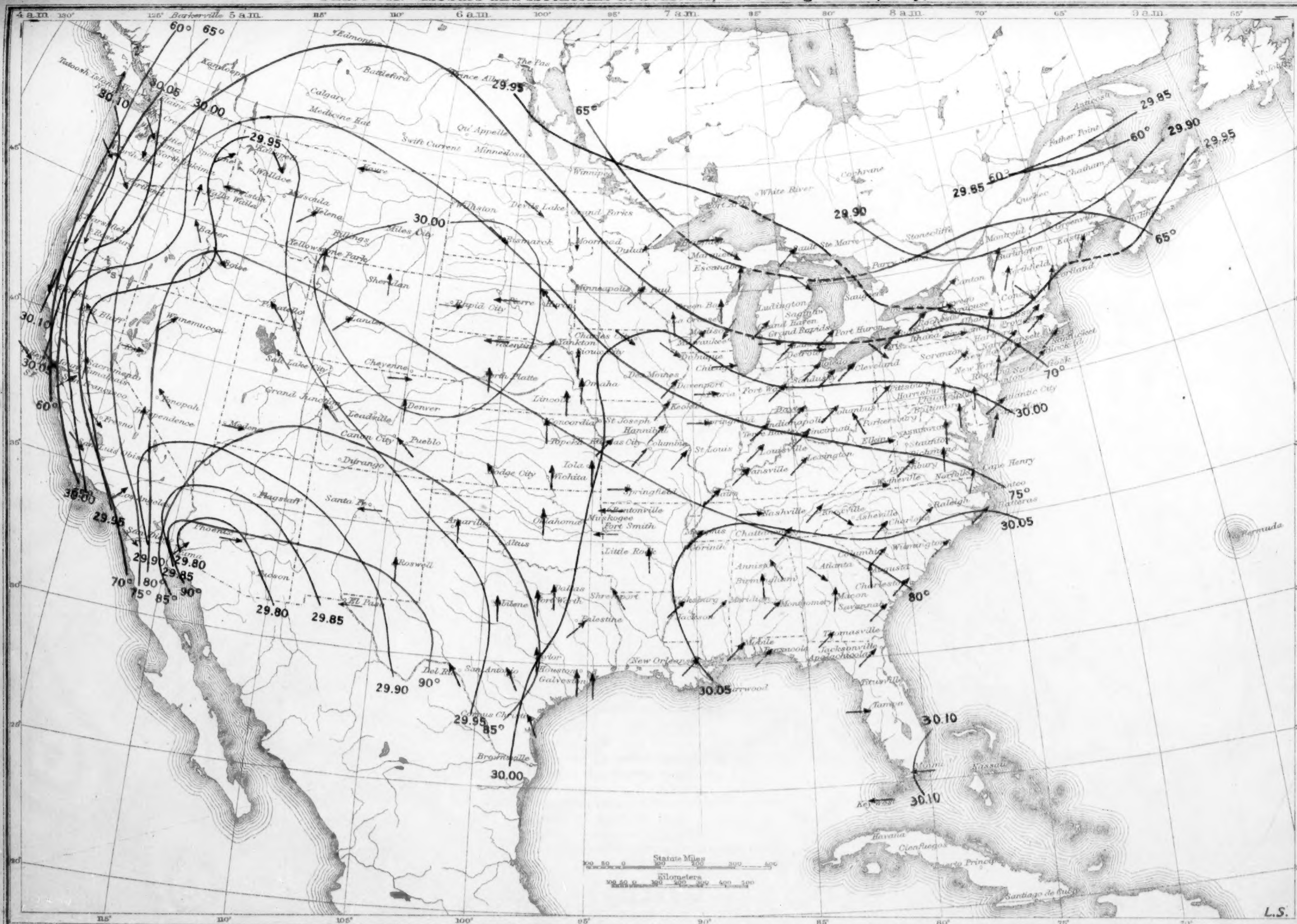

Chart X. Weather Map of North Atlantic Ocean, July 30, 1920.

(Plotted by F. A. Young.)

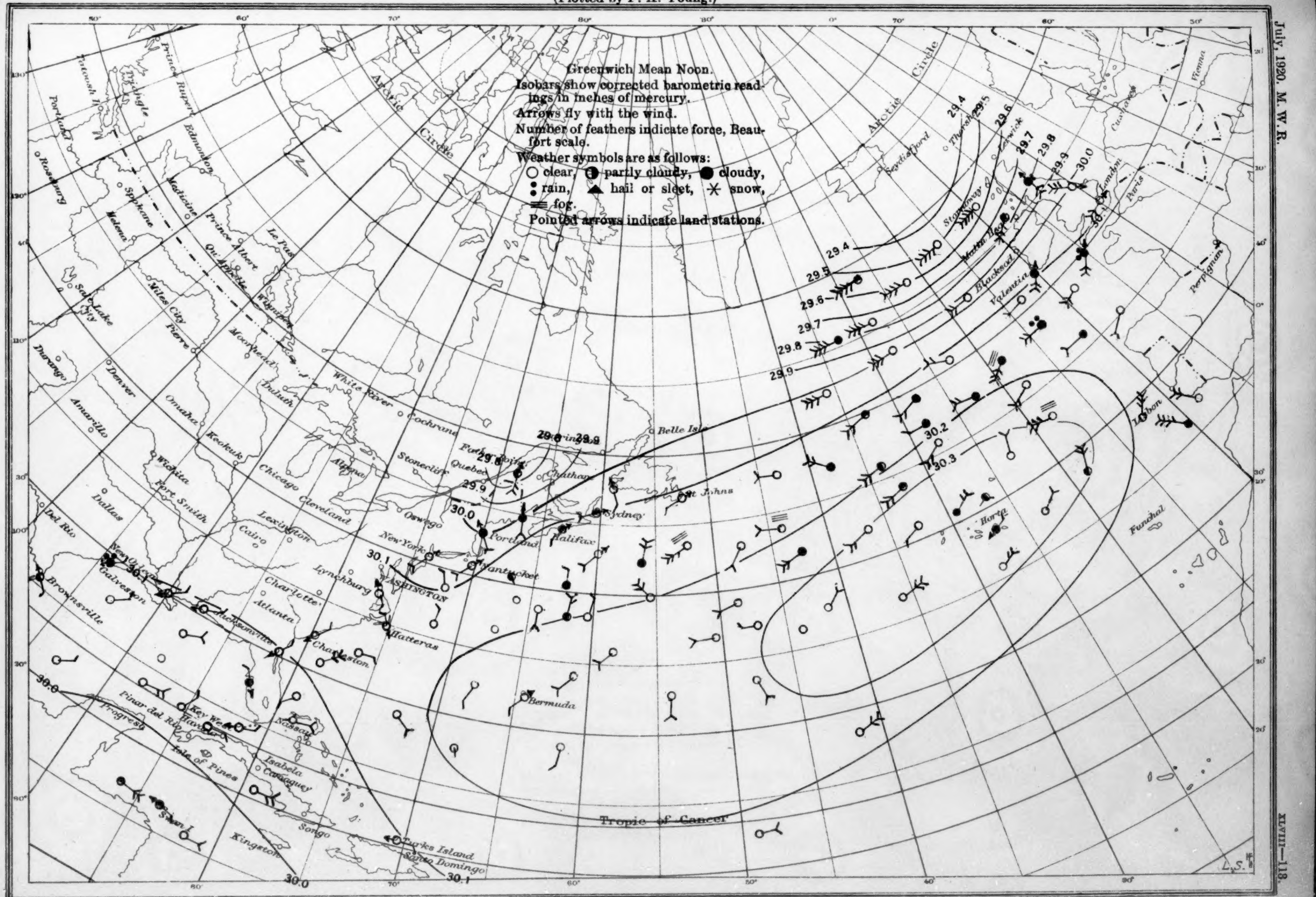

Chart XI. Weather Map of North Atlantic Ocean, July 31, 1920.

(Plotted by F. A. Young.)